THE

JOURNAL

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

CONTAINING
THE PROCEEDINGS

MAY 1910

MEETINGS OF THE SOCIETY: ST. LOUIS, MAY 14; SPRING MEETING, ATLANTIC CITY, MAY 31 TO JUNE 3; MEETING IN ENGLAND, JULY 26 TO 29

MAY 1910 VOL. 32 No. 5

THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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The professional papers contained in The Journal are published prior to the meetings at which they are to be presented, in order to afford members an opportunity to prepare any discussion which they may wish to present.

The Society as a body is not responsible for the statements of facts or opinions advanced in papers or discussions. C55

THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 32 MAY 1910 NUMBER 5

SPRING MEETING, ATLANTIC CITY, MAY 31-JUNE 3

PROGRAM

Tuesday afternoon and evening, May 31

Informal reunion of members in the parlors of the Marlborough-Blenheim.

Wednesday, June 1, 10 a.m.

PROFESSIONAL SESSION

Business meeting. Reports of Committees, Tellers of Election, New Business.

PAPERS ON MACHINE CONSTRUCTION AND OPERATION

THE SHOCKLESS JARRING MACHINE, Wilfred Lewis.

A COMPARISON OF LATHE HEADSTOCK CHARACTERISTICS, Prof. Walter Rautenstrauch.

THE STRENGTH OF PUNCH AND RIVETER FRAMES MADE OF CAST IRON, Prof. A. L. Jenkins.

Wednesday afternoon and evening

The afternoon is left unassigned to give opportunity for sight-seeing. Roller chairs for the board walk will be available for the visiting members and guests through the courtesy of the Local Committee.

In the evening, entertainment on the steel pier has been provided by the committee.

Thursday, June 2, 10 a. m.

PROFESSIONAL SESSION

MISCELLANEOUS PAPERS

THE MECHANICAL ENGINEER AND THE TEXTILE INDUSTRY, H. L. Gantt.

THE ELASTIC LIMIT OF MANGANESE AND OTHER BRONZES, J. A. Capp.

THE HYDROSTATIC CHORD, R. D. Johnson.

THE RESISTANCE OF FREIGHT TRAINS, Prof. Edw. C. Schmidt.

Thursday, 2 p. m.

GAS POWER SECTION

BUSINESS MEETING AND REPORTS OF COMMITTEES.

PAPERS

A REGENERATOR CYCLE FOR GAS ENGINES USING SUB-ADIABATIC EXPANSION, Prof. A. J. Frith.

GAS ENGINES FOR DRIVING ALTERNATING CURRENT GENERATORS, H. G. Reist.

TWO PROPOSED UNITS OF POWER, Prof. Wm. T. Magruder.

SOME OPERATING EXPERIENCES WITH A BLAST FURNACE GAS POWER PLANT, H. J. Freyn.

Thursday, 9 p. m.

Reception, followed by conferring of Honorary Membership on Rear-Admiral George W. Melville, U. S. N., Ret. A brief address will be made by Admiral Melville, and the evening will conclude with dancing and refreshments.

Friday, June 3, 10 a. m.

PROFESSIONAL SESSION

PAPERS ON POWER TRANSMISSION

IMPROVEMENTS IN LINESHAFT HANGERS AND BEARINGS, Henry Hess.

EXPERIMENTAL ANALYSIS OF A FRICTION CLUTCH-COUPLING, Prof. Wm. T. Magruder.

AN IMPROVED ABSORPTION DYNAMOMETER, Prof. C. M. Garland.

CRITICAL SPEED CALCULATION, S. H. Weaver.

REPRESENTATIVE OF THE PROFESSION IN PENNSYLVANIA AND NEW JERSEY

For several years the Spring Meeting of the Society has been held in cities where there has been an opportunity of visiting places of interest and inspecting engineering enterprises, and the time of the members has been very fully occupied in taking advantage of such excursions as the generosity and coöperation of the local members have made possible. While these meetings have all been thoroughly enjoyed, it was thought that it would be a welcome change to hold a meeting at a resort where those attending would have more time for renewal of acquaintance and for personal intercourse, instead of devoting so much attention to matters outside of the interests directly related to the Society and its membership. The last meeting of this sort was the Spring Meeting in 1903 held at Saratoga. The present meeting at Atlantic City should be an equally pleasant occasion, since there is no place in the country better adapted for holding a convention and the meeting is held at a time which is one of the most delightful in which to spend a few days on the New Jersey shore.

The Marlborough-Blenheim Hotel, the Convention headquarters, is situated at the central point of Atlantic City's famous seven-mile board walk, and occupies a block and a half on the ocean front looking southward and 200 yards on the City Park looking eastward. It has a capacity of 1100 and makes many provisions for the comfort of its guests, including the open-air plaza and the solariums overlooking the ocean.

LOCAL COMMITTEE

James M. Dodge, *Chairman*

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J. C. Brooks
James Christie
Morris L. Cooke
Charles Day
Kern Dodge
Francis H. Easby
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S. M. Vauclain
William R. Webster
Tilden White
Walter Wood

MEETING IN ENGLAND

A program of the joint meeting of The American Society of Mechanical Engineers and the Institution of Mechanical Engineers has been issued by the Institution. As already announced this meeting will be held in Birmingham and London and will begin on Monday, July 25. A local committee consisting of the Right Hon. the LORD MAYOR OF BIRMINGHAM, Alderman W. H. Bowater, together with members of the Institution and other gentlemen resident in the neighborhood, has been formed to make the necessary arrangements. A ladies' committee will be formed in Birmingham to make arrangements for the entertainment of ladies accompanying the members of both societies.

PROVISIONAL BIRMINGHAM PROGRAM

Monday, 25th July. Arrival in Birmingham

Tuesday, 26th July

Morning.—The Right Hon. the Lord Mayor of Birmingham and the Members of the Local Committee will receive and welcome the President, GEORGE WESTINGHOUSE, Esq., and the Officers and Members of the American Society of Mechanical Engineers, and the President, JOHN A. F. ASPINWALL, Esq., and the Council and Members of the Institution of Mechanical Engineers.
READING AND DISCUSSION OF PAPERS.
LUNCHEON in the Town Hall.

Afternoon. Visits to Stratford-on-Avon, Worcester, Gloucester, or Bournville; and local Works.

Evening. Garden Fête.

Wednesday, 27th July

Morning. READING AND DISCUSSION OF PAPERS.
LUNCHEON in the Town Hall.

Afternoon. Visits to the University and local Works.

Evening.—RECEPTION in the Council House, by invitation of the Right Hon. the Lord Mayor of Birmingham.

Thursday, 28th July

Visits to Works in Coventry and Rugby; also to Warwick, Leamington, Kenilworth, or Lichfield.

PROVISIONAL LONDON PROGRAM

Thursday, 28th July

Evening.—Conversazione at the Institution.

Friday, 29th July

Morning.—READING AND DISCUSSION OF PAPERS.
Afternoon.—Garden Parties at Private Houses.
Evening.—INSTITUTION DINNER in the Connaught Rooms, Freemason's Hall, Great Queen Street, W. C. (Including Ladies.)

Saturday, 30th July

Morning and Afternoon.—Excursion by Rail and River to WINDSOR and HENLEY.
Evening.—Reception at the Garden Club in the Japan-British Exhibition at the White City.

It is intended that Invitation Cards be handed to the American visitors on their arrival in Birmingham.

The privileges and invitations in connection with the Meeting are *personal* and are *not transferable.*

PRINCIPAL HOTELS CENTRALLY SITUATED IN BIRMINGHAM AND NEIGHBORHOOD

Queen's
Grand
Imperial
Midland
Colonnade
Swan
Plough and Harrow (Hagley Road 1½ miles)
Cobden (Temperance)
Hen and Chickens (Temperance)
Kenilworth (27 miles): King's Head; Manor House
Knowle (10 miles): The Forest
Leamington (23½ miles): Regent; Clarendon: Manor House
Lichfield (18 miles): George; Swan
Stratford (26½ miles): Shakespeare; Red Horse; Red Lion
Warwick (22 miles): Warwick Arms
Wolverhampton (12½ miles): Victoria Star and Garter.

For the convenience of members of The American Society of Mechanical Engineers, who are expected to arrive in Liverpool on Sunday, 24th July, and to proceed by special train to Birmingham on the 25th, a list of the principal hotels in Liverpool and the neighborhood, and in Southport, follows.

PRINCIPAL HOTELS IN LIVERPOOL AND NEIGHBORHOOD

Adelphi, Ranelagh Place
Exchange Station, Tithebarn Street
North Western, Lime Street
Hotel St. George, Lime Street
Angel, Dale Street
Compton, Church Street
Feathers, Clayton Square
Imperial, Lime Street
Stork, Queen Square
Union, Parker Street
Washington, Lime Street
Waterloo, Clayton Square
Laurence's Temperance, Clayton Square
Shaftsbury (Temperance), Mount Pleasant.
Hotel Victoria, New Brighton ($2\frac{1}{2}$ miles by ferry boat)
Leasowe Castle Hydro., Wallasey ($3\frac{3}{4}$ miles)
Royal, Waterloo (5 miles)
Blundell Sands, Blundellsands (6 miles)
Royal, Hoylake ($7\frac{1}{4}$ miles)
New Hydro., West Kirby ($8\frac{1}{2}$ miles)
Chester (15 miles from Birkenhead: Queen Hotel (opposite Railway Station); Grosvenor Hotel (center of City); Blossoms Hotel
Southport ($18\frac{1}{2}$ miles from Liverpool): Prince of Wales, Lord Street; Palace; Royal; Victoria; Waverley; Queen's, all on Promenade.

MEETING IN ST. LOUIS MAY 14

A meeting of the Society will be held in St. Louis, May 14, in which the Engineers Club of St. Louis are to coöperate. The paper will be Freight Train Resistance by Prof. Edward C. Schmidt, which is published in this number of the Journal.

REPORTS

MEETING IN ST. LOUIS APRIL 9

The meeting of the engineers of St. Louis, April 9, was conducted by The American Society of Mechanical Engineers with the coöperation of the St. Louis Section of the American Institute of Electrical Engineers as well as of the Engineers Club of St. Louis A symposium on Electric Drive in the Machine Shop was presented, to which three papers were contributed by the Society: The Economy of the Electric Drive, by A. L. DeLeeuw, Mem. Am. Soc. M. E.; Economical Features of Electric Motor Applications by Charles Robbins, of the Westinghouse Electric and Manufacturing Company, and associate member of the American Institute of Electrical Engineers; Mechanical Features of Electric Driving, by John Riddell, Mem. Am. Soc. M. E. A paper, Selection and Methods of Application of Motors and Controllers, by Charles Fair, of the General Electric Company, a member of the Institute was contributed by the American Institute of Electrical Engineers. The attendance was nearly 100.

MEETING IN NEW YORK APRIL 12

The New York monthly meeting was held Tuesday evening, April 12, in the Auditorium of the Engineering Societies Building, with the American Institute of Electrical Engineers coöperating. The subject was Electric Drive in the Machine Shop with the four papers listed above under the meeting at St. Louis.

This subject of electric driving has long been in preparation with a view to presenting in the papers and discussions the recent developments in electric motor applications to machine tools and the economic features of such applications where motors are installed either for direct driving or in connection with lineshafts for group driving. The economic side was very fully discussed by representatives of the machine tool industry ando ther users of motors as well as by the motor manufacturers. Mr. Fred. L. Eberhardt, Vice-President of the National Machine Tool Builders Association, spoke officially for his

organization of their efforts, with the American Association of Electric Motor Manufacturers, for the securing of standards for motor equipment. Mr. A. L. DeLeeuw, a member of the committee of the National Machine Tool Builders Association to consider this subject, followed with a detailed account of the efforts at standardization to date, in which he said fifteen points had been raised for discussion and that seven of them had been considered by the joint committee thus far, among them being the subjects of horsepower, voltages, speeds and ratings.

The papers were also discussed by Henry Hess, of the Hess-Bright Manufacturing Company, Philadelphia, Pa.; L. R. Pomeroy, of the Safety Car Heating & Lighting Company, New York; Gano Dunn, Vice-President of the Crocker-Wheeler Company, Ampere, N. J.; Charles Day, of Dodge & Day, Philadelphia; W. S. Rogers of the Bantam Anti-Friction Company, Bantam, Conn.; Carl G. Barth, Philadelphia; and H. A. Horner, Philadelphia.

MEETING OF THE COUNCIL

A meeting of the Council was called to order in the rooms of the Society, April 12, 1910. Present, Messrs. George M. Bond, Chas, Whiting Baker, J. Sellers Bancroft, H. L. Gantt, James Hartness, Charles Wallace Hunt, F. R. Hutton, I. E. Moultrop, E. D. Meier, H. G. Reist, Frederick W. Taylor, Jesse M. Smith and the Secretary. In the absence of the President, Col. E. D. Meier took the chair.

The Secretary announced the deaths of James Blessing and Gardiner C. Sims.

The resignations of A. E. Coleman, Jr., Zareh H. Kevorkian, George E. Kirk, J. E. Tatnall and Ephraim Smith were read and accepted, and the membership of Thomas M. Keith, George L. Holmes, Barton H. Cameron, Rafael de la Mora, W. Allen Pendry, Edward S. Seaver and Charles L. Weil was declared to have lapsed.

Voted: To accept the report of the special committee appointed by the Council to go to St. Louis, and to express the very hearty appreciation of the Council; and to refer the report to the Executive Committee.

The Executive Committee reported as the total booking on the Celtic, to date, of those who will attend the Joint Meeting in England: 144 members and ladies; going by other routes or already in Europe 81 making a grand total of 225.

Voted: To appoint as a Committee on Arrangements, in con-

nection with the joint meeting in England, Ambrose Swasey, *Chairman*, Charles Whiting Baker, *Vice-Chairman*, Dr. W. F. M. Goss, George M. Brill, John R. Freeman, and, ex-officio George Westinghouse, President, William H. Wiley, Treasurer, F. R. Hutton, Honorary Secretary, Willis E. Hall, Chairman Meetings Committee, and Calvin W. Rice, Secretary.

The Secretary reported that fifteen members of the Council and Past-Presidents expected to attend the dinner to by given by President Aspinwall, on the evening of Monday, July, 25.

Voted: That Charles Whiting Baker be appointed Honorary Vice-President, to represent the Society at the International Congress of Mining Metallurgy, Applied Mechanics and Practical Geology. The Secretary also presented to Mr. Baker the appointment from the State Department as delegate from the United States.

Voted: To appoint Worcester R. Warner Chairman of the Committee on Land Fund.

Voted: To refer to the Executive Committee, with power, in the matter of coöperation with the Verein Deutscher Ingenieure in the preparation of biographies of eminent engineers.

Voted: To approve the applications for a Student Branch at the University of Arkansas, Fayetteville, Ark.

Voted: To adopt the following amendments:

ELECTION OF MEMBERS

B 11 Each person elected to membership, except an Honorary Member must subscribe to the Constitution, By-Laws, and Rules of the Society, and pay the initiation fee before he can receive a certificate of membership in the Society. Resignations from membership shall be presented to the Council for action.

FEES AND DUES

B 16 The initiation fee and the annual dues for the first year shall be due and payble on the first day of the month following the date of the election of a Member, Associate, or Junior. The annual dues for each ensuing year shall be due and payable in advance on the corresponding day in each year thereafter.

Upon the payment of the initiation fee and the annual dues for the first year the person elected shall be entitled to the rights and privileges of membership in the grade to which he was elected. The date of payment of a member's annual dues may be changed to the first day of any other month, and a *pro-rata* adjustment of the dues made, by application to the Secretary.

B17 A Member, Associate or Junior in arrears for dues for one year, on the first day of October previous to the annual Meeting, shall not be entitled to vote, or to receive the transactions or the publications issued by the Society

thereafter until such dues have been paid. Should the arrears for dues or otherwise be for more than two years, the name of such person shall be presented to the Council for such action as it deems advisable under C 24. Should the right to vote, or to receive the publications of the Society be questioned, the books of the Society shall be conclusive evidence.

B 18 The council may, in its discretion, restore to membership any person dropped from the roll for non-payment of dues, or otherwise, upon such terms and conditions as it may at the time deem best for the interests of the Society.

Voted: That the Council accept the invitation of the National Steam and Hot Water Fitters Association to a conference leading to the adoption of uniform standards for flanged and screwed cast-iron fittings, and that the Secretary communicate with the various members of the Council and specialists in power-house practice and ask their suggestions for names for such a committee.

Voted: That a message of congratulation and greeting be sent to the Aero Club of American on the opening of the club rooms on the evening of Wednesday, April 13, in the Engineering Societies Building.

Voted: That Charles Whiting Baker be appointed Chairman of a Committee, with power to increase the number to investigate the matter of a proposed bill now before the legislature to license engineers, and to report to the Council at its next meeting.

REQUEST FOR 1903 YEAR BOOK

A copy of the Year Book for 1903 is needed to complete the files of the Society. Any member willing to furnish a copy will please communicate with Calvin W. Rice, Secretary, at the rooms of the Society.

STUDENT BRANCHES

PENNSYLVANIA STATE COLLEGE

At the March meeting of the section held March 16, the topic for the evening was Methods of Coal Mining, which was ably handled by George B. Wharen, A. F. Goyne and Roy B. Fehr (1910). The papers were supplemented by views of mines and mine apparatus thrown on the screen. At the April meeting, Refrigeration and Cold Storage will be discussed.

PURDUE UNIVERSITY

On March 24, F. H. Clark, Genl. Supt. M.P. of the C. B. & Q. R. R. addressed the student section of Purdue University on The Functions and Work of the Motive Power Department, followed by a general discussion in which many points of interest were enlarged upon. Professor Ensley, of the university, addressed the meeting on April 6, on Recent Developments in Brake Shoe Tests, on whichhe is an authority. His address was supplemented by lantern slides.

UNIVERSITY OF CINCINNATI

The student branch of the University of Cincinnati had as the speaker at its meeting on March 25, James B. Stanwood, Mem.Am. Soc.M.E., who presented a very interesting paper on The Development of Non-Condensing Engines. Harry M. Lane, Mem.Am.Soc. M.E., gave a discussion of the paper. At the meeting on April 15, William Goodman, manager of Laidlaw-Dunn-Gordon Company, presented a paper on Air Compressors and their Manufacture.

WISCONSIN UNIVERSITY

At the April meeting of the section, G. A. Glick (1910) presented a paper on A 15,000-kw. Steam Engine Turbine Plant, based on Mr. Stott's paper published in The Journal, March issue. The paper was followed by a discussion in which Assistant Professor A. G. Christie told of some of the difficulties encountered in testing the engines referred to in the paper. The following officers were elected; President, John S. Langwill; Vice-President, Henry A. Christie; Corresponding Secretary, Karl L. Kraatz; Assistant Secretary, Guy H. Suhs; Treasurer, Angus MacArthur.

OTHER SOCIETIES

INTERNATIONAL CONGRESS OF MINING, METALLURGY, APPLIED MECHANICS AND PRACTICAL GEOLOGY

Charles Whiting Baker, Vice-President of the Society, has been appointed Honorary Vice-President to represent the Society at the International Congress of Mining, Metallurgy, Applied Mechanics and Practical Geology, to be held at Düsseldorf, Germany June 20–23, 1910. Mr. Baker has also received appointment from the State Department as delegate from the United States.

BOSTON SOCIETY OF ARCHITECTS

At the dinner of the Boston Society of Architects, held at the Parker House, April 1, 1910, Calvin W. Rice, Secretary Am. Soc.M.E., was the guest of honor. The topic for consideration was Office Organization. Mr. Shreave of Carrere & Hastings was also a guest and spoke from knowledge not only of the office with which he is connected, but also of that of McKim, Mead & White.

Mr. Rice took occasion to explain the necessity of organization in the office of the society, as in a business, for the reason that members of the society who are business men expect efficient service whenever they communicate with the society on any matter. The Society is essentially an organization of trained men. The variety of the inquiries, several hundred a day, also requires a complete staff, and it must be organized if useful and practical attention is to be given these inquiries. The most important idea in connection with an engineering society is that, in a larger sense than the individual, it must serve the profession; rather than that it is simply an aggregation of persons for selfish interests. In other words, the association must be organized for progressive and helpful work. Such is the organization of The American Society of Mechanical Engineers.

AMERICAN ELECTROCHEMICAL SOCIETY

In response to a request, the Secretary has sent to Dr. Jos. W. Richards, South Bethlehem, Pa., secretary of the American Electrochemical Society, a list of members of this Society resident in the Pittsburg district, who are to be specially invited to the convention to be held at Pittsburg, May 5-7. C. E. Foster, Mem.Am.Soc.M.E., and John Brashear, Hon.Mem.Am.Soc.M.E., are among the speakers. Further announcement will be found on a later page of The Journal.

NECROLOGY

WILLIAM WILBERFORCE CHURCHILL

William Wilberforce Churchill died at Oshkosh, Wis., on March 24, 1910. He was born at Monroe, Wis., January 6, 1867, and was the son of Norman and Dr. Ann Sherman Churchill. After graduation from the Monroe High School in 1883, he spent one year at Rose Polytechnic Institute, and in 1886 entered Cornell University, from which he was graduated in 1889 with the degree of M.E. He was made a Fellow of Sibley College for 1889–1890, and received the degree of M.M.E. in 1890.

After graduation Mr. Churchill spent a few months with E. P. Allis & Co., Milwaukee, Wis. In 1890 he entered the employ of Westinghouse, Church, Kerr & Co., where he remained until his retirement because of a breakdown in health, in 1906. He rose through various intermediate positions in Chicago, Pittsburg and Boston to be chief mechanical engineer of the company's headquarters in New York. At the time of his retirement he was vice-president and director in the company. During his sixteen years of service he superintended the construction of the Boston terminal; the Kingsbridge power house, New York City; the Atlanta water plant, Georgia; the Lackawanna & Wyoming Valley R. R., Pennsylvania; The Grand Rapids, Grand Haven & Muskegon R.R.; Hotel Pontchartrain, Detroit, Mich.; the Northern Colorado Power Company, Denver, Colo.; the electrification of the Long Island R. R., New York, and many others. In 1902 he spent some time in Europe in connection with the electrification of the London Underground Railway.

Mr. Churchill was a member of the New York Railroad Club, the Cornell University Club, New York, the American Association for the Advancement of Science, and several Masonic orders.

GARDINER C. SIMS

Gardiner C. Sims, president of the William A. Harris Steam Engine Company, died at his home in Providence, R. I., on March 20, 1910. Mr. Sims was born in Niagara Falls, N. Y., July 31, 1845, and was educated there in the public schools. He began his engineering career with a four years' apprenticeship at the locomotive works of the N. Y. C. & H. R. R. R., West Albany, N. Y., afterward entering the navy yard at Brooklyn, N. Y., but returning to his former employers after three years, to become their chief draftsman. He next became

superintendent of the J. C. Hoadley Engine Works at Lawrence, Mass. Here he met Pardon Armington, with whom he formed a partnership for the manufacture of steam engines, both men devoting their ntire time to experimental work as a result of which they gave to the world the quick-running engine, in opposition to the established engineering practice and precedents. They built the first successful engine for Thomas A. Edison, which was sent to the Paris Exposition with his first dynamo, in 1881.

In 1876 Mr. Sims spent eight months at the Centennial Exposition and was appointed Democratic Commissioner from the State of Rhode Island to the World's Columbian Exposition in 1892, where he was made chairman of the Exposition committee on electricity, electric and pneumatic appliances, and was a member of the committee on machinery and transportation.

At the outbreak of the war with Spain, Mr. Sims volunteered, and was appointed Chief Engineer by the Navy Department and ordered to the navy yard at Boston. For his work in this branch of the service Mr. Sims was made a Lieutenant Commander and received congratulatory letters from Secretary Long and Engineer-in-Chief George W. Melville.

At the close of the war he was summoned by the War Department to assume the position of Superintendent Engineer of the United States Army Transport Service, and discharged his duties with honor until the completion of the work. He was appointed police commissioner in 1902, and at the time of his death was connected with the William A. Harris Steam Engine Company.

HARRY S. HASKINS

Harry S. Haskins, Associate Member of the Society, died at his home in Philadelphia on March 13, 1910. Mr. Haskins was born in Moretown, Vt., March 5, 1831, and at the age of twelve entered the machinists trade, first with Edwin Harrington and later with the Junction Shop, both in Worcester, Mass., where his family had moved. When Mr. Harrington went to Philadelphia, to engage in the building of machine tools, Mr. Haskins accompanied him, and soon afterwards the partnership of Harrington & Haskins was formed, which later became the firm of Edwin Harrington, Sons & Co. On the death of Mr. Harrington, the business became incorporated, with Mr. Haskins as president, an office which he retained until the time of his retirement, in 1900. Throug his mechanical ability and inventive faculty he added many improvements to the gear-cutting machines, hoists and overhanging railways manufactured by the firm.

FREIGHT TRAIN RESISTANCE

ITS RELATION TO AVERAGE CAR WEIGHT

By Prof. Edward C. Schmidt, Urbana, Ill.

Member of the Society

CONTENTS

Train resistance varies not only with the train speed, but also with the average weight of the cars of which the train is composed. At a given speed the tractive effort required for each ton of weight of the train will be greater, for example, for the train which is composed of cars of twenty tons average gross weight, than for the train composed of cars which weigh, on the average, fifty tons each.

2 While this fact has been known for some years, it has found inadequate expression and but little application. In the establishment of their tonnage ratings many railroads have altogether ignored it. In the tonnage ratings of a few roads this variation of resistance with car weight is recognized to the extent of allowing a difference in rating between trains composed of loaded cars and those consisting entirely or partially of empty cars. Generally in such systems a certain amount is allowed arbitrarily, to be added to the weight of empty cars in determining, for the purpose of rating, the weight of the train in which they are found. In such rating no distinction is made between loaded cars of various weights, although such weights vary from 25 to 70 tons.

The American Society of Mechanical Engineers, 29 West 39th Street, New York. All papers are subject to revision.

3 A still smaller group of railroads have fully recognized the significance of the facts above stated in establishing their tonnage ratings, which in such cases are usually termed "adjusted" or "equated" ratings. Under these adjusted ratings the actual weight of the train allotted to a particular locomotive varies according to the number of cars in the train. The rating for the same locomotive, with trains of 40, 60, and 80 cars, for example, will be different in each of the three cases. This, of course, is in effect a variation of the rating with respect to the average car weights.

4 Most of these adjusted ratings have been empirically determined. In the few cases where they rest upon experiments made to determine the variations in train resistance with respect to car weight the data and results of such experiments have not been fully published. Existing train resistance formulæ likewise fail in most cases to take into account these variations of resistance with car weight; and probably much of the divergence among them is properly to be ascribed to this fact.

5 *Purpose of the Tests.* In view of the facts just stated it has seemed desirable to make the tests whose results are here recorded. They were planned to determine the resistance of freight trains under the usual conditions of operation; and were designed to disclose at the same time, if possible, the relation existing, at any given speed, between train resistance and average car weight. Since the chief use of such information is in the production of locomotive ratings, the conditions of the tests have been made like those which prevail in normal freight train operation. The speed range, for example, is from 5 to 35 miles per hour; and the trains experimented upon were trains in regular service, and usual in their make-up. The track upon which the tests were made is believed to be representative of good main line construction.

6 The tests have been made as part of the research work of the Engineering Experiment Station of the University of Illinois, conducted by the railway engineering department. They were begun in April, 1908, and were completed in May, 1909 All tests were made by means of Test Car 17, a dynamometer car, owned jointly by the University of Illinois and the Illinois Central Railroad, and were carried out on the Chicago division of this road.

7 In the preparation of the report the aim has been to present in it as brief a statement of the results and conditions as is compatible with a clear understanding of the tests. The results of the tests will also be published as a bulletin of the Engineering Experiment Station

of the University of Illinois. This bulletin will contain, in addition to the facts here presented, more detailed information concerning the track, the dynamometer car, and the methods of calculation; as well as the tonnage record for each train and the results and resistance curve for each test. A summary of the test conditions and the conclusions is inserted immediately beyond.

8 Throughout the report the terms "resistance" and "train resistance" mean the number of pounds of tractive effort required for each ton of the train, in order to keep it in motion on straight and level track, at uniform speed, and in still air. The report deals exclusively with the resistance of the train behind the locomotive tender. Locomotive and tender resistance are not discussed.

9 *Acknowledgments.* The tests have been made possible through the interest and coöperation of Mr. William Renshaw, Mr. J. G. Neuffer, and Mr. R. W. Bell, who were successively superintendents of machinery of the Illinois Central Railroad during the period of planning and conducting the work. Many other officials of the Chicago division of the road have rendered generous assistance in the investigation, which has entailed for them not a little inconvenience and labor. Such interest and assistance are thoroughly appreciated by those of the university staff who have been concerned with the work.

10 Throughout this work, the operation of the dynamometer car and the making of the calculations have been under the direct supervision of Mr. F. W. Marquis, Associate in the railway engineering department, Engineering Experiment Station. Much of whatever accuracy and reliability have been attained in the investigation is due to his intelligent and painstaking care in making the tests and in systematizing the work of calculation. He has also rendered great assistance in supervising the preparation of the tables and illustrations, and in the final checking of the manuscript.

SUMMARY AND CONCLUSIONS

11 *Summary.* The report deals with the results obtained from tests of thirty-two ordinary freight trains, whose chief characteristics were as follows:

	Minimum	Maximum
Total weight, tons	747	2908
Average weight per car, tons	16.12	69.92
Number of cars in the train	26	89

The trains whose average weights were less than 20 tons or more

than 60 tons were composed of cars of nearly uniform weight; while those whose average car weights were between 20 and 60 tons were either homogeneous or mixed as regards the weight of the individual cars.

12 The tests were made during generally fair weather. The minimum air temperature during any test was 34 deg., the maximum 82 deg. The approximate average wind velocity prevailing throughout one test was 25 miles per hour; during all the others it was less than 20 miles per hour.

13 The tests were made upon well constructed and well maintained main-line track, 94 per cent of which is laid with 85-lb. rail, the remainder being laid with 75-lb. rail. Except through station grounds, where screenings or cinders are used for ballast, the track is full ballasted with broken stone.

14 *Conclusions.* The results of the tests are presented in Figs. 10 and 11, in Table 3, and in the equations accompanying Par. 75. The curves, the table, and the equations, are each different expressions of the same facts. It is believed that by their use one may safely predict the probable total resistance of *entire* freight trains at various speeds, when running upon straight and level track of good construction, during weather when the temperature is above 30 deg. fahr., and the wind velocity not more than 20 miles per hour; provided the *average* weight of the cars composing the train be known.

15 The results are applicable to trains of all varieties of make-up to be met with in service. They may be applied, without incurring material error, to trains which are homogeneous and to those which are mixed, as regards individual car weight.

16 The results are primarily applicable to trains which have been for some time in motion. When trains are first started from yards, or after stops on the road of more than about twenty minutes duration, their resistance is likely to be appreciably greater than is indicated by the results here presented. In rating locomotives no consideration need be given this matter, except in determining "dead" ratings for low speeds, and then only when the ruling grade is located within six or seven miles of the starting point or of a regular road stop.

17 It is to be expected that some trains in service will have a resistance about 9 per cent in excess of that indicated by Figs. 10 and 11, due to variations in make-up or external conditions within the limits to which the tests apply. If operating conditions make it essential to reduce to a minimum the risk of failure to haul the allotted tonnage, then this 9 per cent allowance should be made. This con-

sideration, like the one preceding, is important only in rating locomotives for speeds under 15 miles per hour. At higher speeds, the occasional excess in the resistance of individual trains will result in nothing more serious than a slight increase in running time. It should be emphasized that this allowance, if made, is to be added to the resistance on level track—not to the gross resistance on grades.

THE METHODS AND MEANS EMPLOYED IN CONDUCTING THE TESTS

18 The tests were carried on by means of the dynamometer car here referred to as Test Car 17, which, when not in use, is held at Champaign, a district terminus. The car was operated from time to time in the regular trains leaving this point, and the trains selected were partly in the northbound, partly in the southbound traffic.

19 The plan was to determine, for each of the trains experimented upon, the relation of its resistance to its speed. This information was to be finally expressed as a resistance-speed curve such as is shown in Fig. 1. The trains were so selected that their average car weights varied through as great a range as possible. As will later appear, this range proved to be from the weight of an empty gondola to that of a fully loaded car of 100,000-lb. capacity. It was the expectation that when the resistance-speed curves of the individual tests were brought together, their analysis would reveal the relations existing between train resistance and car weight.

20 During each test the following information was obtained:

a The drawbar pull of the locomotive upon the train.
b The train speed.
c A continuous record of time elapsed from the beginning of the test.
d The pressure existing in the brake cylinder of the test car.
e The direction of the wind relative to the direction of motion of the car.
f The velocity of the wind relative to the car.
g A record of the location of the test car upon the road.
h Air temperatures and other weather conditions.
i Data concerning the train, such as its weight, etc.

The information cited under Items *a* to *g* was obtained in the form of continuous graphical records upon the chart which is produced by the apparatus of the dynamometer car. By means of this chart any of the quantities mentioned may be determined at any point upon the road.

21 The curves of drawbar pull and speed provide the informa-

tion essential to the investigation. Supplemented by an accurate profile and a record of train weight, they enable net train resistance to be calculated at any position of the train upon the road. The time record provides a means of calibrating and checking the speed curve. The pressure in the brake cylinder was recorded merely to make it possible to distinguish those periods during the test when the brakes were applied to the train; it being obviously necessary to ignore such portions of the record when making the calculations.

22 The relative wind velocity and relative wind direction were obtained by means of an anemometer and a wind vane mounted on the roof of the test car. When compounded with the known speed and direction of motion of the car, these data permit the determination of the actual wind direction and wind velocity with respect to the track, which were recorded in each test for each point at which train resistance was determined. It is probable that these wind data are, under some circumstances, subject to a considerable error. Considering the length of the run made with each train and the length of time it was on the road, it is believed the data are, nevertheless, more reliable than those which might have been recorded by stationary instruments located at one or two points along the track.

23 Item *g*—the location of the car upon the road—was defined by marking upon the test-car record the position of mile posts and stations at the moment they passed the car. By means of this record it is possible to correlate any position of the train with the road profile.

24 Data concerning the train were obtained by one or two observers who had no other duties. With the one exception noted beyond, all trains were weighed to determine their tonnage. In addition to its weight, there was recorded for each train, its length[1] and for each car its number, kind, stenciled "light weight," gross weight, capacity, and the initials of the owning road.

25 All test-car instruments were calibrated before the tests, and their calibrations were frequently checked during the progress of the investigation. All observers were men experienced in the operation of the test car, and many of them had participated also in the work of calculation, and were consequently aware of the points at which alertness and care were especially needed. No effort has been spared, in conducting the tests, to ensure accuracy in the data. These facts

[1] Train length was determined by counting, during the test, the number of rail lengths corresponding to the length of the train and multiplying this number by 30 ft., which is the rail length for this track.

are here mentioned as having some significance to one who may undertake to estimate the reliability of the results. The Appendix contains an illustration of one of the test-car charts and a description of the car itself.

26 This report includes the data and results from tests of thirty-two different trains. For the purposes of this research, tests were made of twelve other freight trains; but their results were finally excluded from the report. Three of these additional tests were rejected because of uncertainty about the train weights, one because of a breakdown in the test-car recording apparatus during the progress of the test, and eight were disregarded because the temperatures prevailing were below the range for which it was intended the results should apply; the low temperature in some cases being coupled with high wind.

TEST CONDITIONS AND TRAIN DATA

27 *The Trains Tested.* The test trains were all of such make-up as naturally resulted from the traffic conditions in the Champaign yards. For most of the tests the test car was simply coupled into the trains selected by the trainmaster, solely with reference to his convenience in operating and in returning the test car. As the investigation progressed, it became apparent that the accumulated data left certain gaps in the range of average car weights. There were at this stage, for example, few trains experimented upon with average car weights near 25 to 30 tons, and none with an average car weight of 70 tons. The last six or eight trains were therefore made up especially to supplement the data at these points. It should be understood, however, that nothing in this process resulted in a train-make-up which was in any respect unusual. All the trains tested are, therefore, such as one might expect to find upon any road where the traffic conditions are normal. They include trains made up almost entirely of empty gondolas,[1] others with considerable variation in both load per car and kind of car, and still others composed almost entirely of loaded box cars or of loaded gondolas.

28 Test S-1018 demands special mention in this connection. The train for this test included Illinois Central Railroad locomotives No. 423 and No. 732, weighing respectively 145,200 and 223,600 lb.

[1] Cars are designated as box, stock, gondola, flat and tank cars. The term box car is made to include refrigerator cars, the test car and the caboose. The term gondola includes all unroofed cars with sides, such as coal cars, hopper cars, etc.

Their combined weight constituted 13.6 per cent of the total train weight. These locomotives, with their tenders, were being hauled "dead" and had the main rods disconnected, as is usual in such cases. The first is of the 2–6–0 type, the second of the 2–8–0 type, and they and their tenders had therefore together seventeen axles in operation. For the purpose of determining the average car weight for this train, these two locomotives were assumed to be equivalent, in their resistance, to a number of cars having a like number of axles, i.e., 4¼ cars. The results of the calculations warrant the belief that this view of the situation has resulted in no material error. A study of Table 1 will make clear the diversity in the composition of the trains.

29 All trains, except Nos. S-1016, S-1018, S-1030A and S-1030B, were weighed upon one of the two track scales at Champaign. This weighing was done in the usual manner, by pulling the train over the scales and weighing the cars successively without uncoupling. These track scales were in good condition and were each inspected four times during the test period, these inspections disclosing a maximum error in one scale of $-\frac{1}{5}$ per cent, in the other of $-\frac{1}{2}$ per cent. The train in Test S-1016, composed entirely of empty cars, by an error in arrangement left the yards without being weighed. The weights stencilled on the cars were accepted as correct in this case. The train in Test S-1018 was weighed upon track scales in the Chicago yards; and the trains of Tests S-1030A and S-1030B were weighed in the yards at Centralia. In Test S-1021, after leaving the yards, two cars were added to the train, for which the weights were determined from the stencilled weights and the way-bills. In Tests S-1030B and S-1048 the weights of one and two cars respectively were similarly determined, and in Test S-1061 the stencilled weight was used for one empty car. Obviously no important errors in the total tonnage have resulted from possible inaccuracies in the weights of these cars.

30 All cars of all trains were of course provided with the usual four-wheeled truck. Presumably the majority of the cars had journals conforming to the specifications of the Master Car Builders' Association, which for some years have required that freight car journals be either 3¾ in. by 7 in., 4¼ in. by 8 in., 5 in. by 9 in., or 5½ in. by 10 in. in size, depending upon the car capacity. It is safe to assume that all trucks were provided with wheels of 33 in. standard diameter.

31 Throughout each test, observations were repeatedly made to discover such irregularities as hot journal boxes, brakes which were not free from the wheels, and trucks which did not freely follow the track. Such things occurred to the usual extent; a hot-box or two or

an unreleased brake being occasionally found on some of the trains, while others were entirely free from such defects. The record of such matters was given consideration in making the calculations; but, as was anticipated, the results showed no discrepancies which could be explained by such causes.

32 The range over which the train data for all of the tests varied is as follows:

	Minimum	Maximum
Total train weight, tons	747	2908
Average weight of cars composing the train, tons	16.12	69.92
Number of cars in the train	26	89
Train length, ft	1120	3480

33 *The Track.* The track upon which the experiments were carried on extends from Gilman to Mattoon, Ill., a distance of 91 miles, and lies upon the Chicago division of the main line of the Illinois Central Railroad. Until about 10 years ago this was a single-track road and one of the oldest in the State. At that time a second track was constructed, and the roadbed for both tracks is now well settled and in good condition. The maximum grade against north-bound traffic is 29 ft. per mile, and against southbound traffic, 31.9 ft. per mile. In all the 91 miles there are only 7850 ft. of curved track.

34 Through station grounds the tracks are ballasted with screenings or cinders; all other portions of both tracks (about 83 of the 91 miles) are full ballasted with broken limestone. The cross-ties are of oak, laid 20 in. center to center. About $10\frac{1}{4}$ miles of the west track is laid with 75-lb. A.S.C.E. rail, put down in 1894 and 1895; while the remainder of the west track and all of the east track is laid with 85-lb. A.S.C.E. rail, the oldest of which was put down in 1900. During 8 months of the year there is employed in maintaining this portion of the road a force of men which averages one man per mile of track; during the other 4 months this force is reduced to one man for each 2 miles. As regards both construction and maintenance this track is such as one may expect to find upon the main lines of first-class railroads.

35 These 91 miles of track were especially surveyed, immediately preceding the tests, by the railway engineering department of the university for the purposes of this and similar investigations. The levels were run on the east track, and readings were taken to 0.1 ft. at stations 300 ft. apart; and turning points were taken at every fourth

TABLE 1 SUMMARY OF TEST CONDITIONS AND TRAIN DATA

Test Lab. Serial No.	Test Date	Weather Conditions	Air Temp. Deg. F. Beginning of Test	Air Temp. Deg. F. End of Test	Ave. Approx Wind Velocity Miles per Hour	Range of Direction of Wind with Respect to Track* From	Range of Direction of Wind with Respect to Track* To	Train Data† Train Length Feet	Weights: Gross Train Weight Tons	Weights: Average Gross Weight per Car Tons	Cars in Train Total No.	Train Make-up: Conditions of Loading Empty Cars No.	Loaded Cars No.	Loaded Cars %	Train Make-up: Kind of Cars Box Cars %	Gondola Cars %	Flat Cars %	Tank Cars %
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	1908																	
S-1013	4/27	Wet	42	44	19	+35°L	+90°L	2784	2549	38.04	67	10	57	85	82	13	0	5
S-1015	4/29	Fair	40	48	10	+25°L	−80°L	2520	2489	36.08	69	8	61	88	68	6	16	10
S-1016	4/30	Fair	44	48	10	+15°R	+60°R	3030	1161	16.12	72	72	0	0	3	97	0	0
S-1017	5/1	Wet	48	54	16	+45°L	−80°L	2670	2532	38.44	66	13	53	80	95	5	0	0
S-1018‡	5/2	Fair	40	45	11	+10°R	+85°R	2130	1353	25.40‡	49‡	34	15	31	61	6	16	17
S-1019	5/9	Fair	44	62	25	+20°R	+45°R	3480	1572	17.72	89	75	14	16	34	58	7	1
S-1021	5/13	Wet	66	70	17	+60°R	+80°R	2400	2908	46.16	63	10	53	84	32	60	5	3
S-1023	5/23	Fair	62	74	17	+75°R	−80°R	2320	2243	38.72	58	17	41	71	45	52	0	3
S-1027	7/2	Wet	64	80	14	−50°R	+70°R	1710	2185	47.44	46	3	43	94	22	76	2	0
S-1030A	7/8	Fair	60	68	6	+20°R	+65°R	1380	2036	59.88	34	2	32	94	6	94	0	0
S-1030B	7/8	Fair	68	72	7	+20°R	+65°R	1650	2342	57.12	41	3	38	93	20	80	0	0
S-1031	7/22	Fair	70	82	5	+ 0°	+40°L	1425	747	20.72	36	30	6	17	94	3	3	0
S-1033	9/26	Fair	66	82	12	+ 5°L	+15°R	1710	2275	51.70	44	2	42	95	5	95	0	0
S-1034	10/3	Fair	42	60	4	− 0°	+85°L	3015	1259	16.56	76	76	0	0	1	99	0	0
S-1036	10/10	Fair	40	62	6	+15°R	−15°R	2010	1961	37.72	52	8	44	85	73	25	2	0

S-1038	10/15	Fair	58	72	16	+ 5°L	+25°L	1650	2144	52.28	41	3	38	93	22	78	0	0
S-1040	10/24	Wet	57	53	11	+15°R	+40°R	1830	2152	45.76	47	2	45	96	49	49	0	2
S-1043	11/7	Fair	38	53	8	+ 5°R	+65°R	2580	1118	16.92	66	65	1	2	24	74	0	2
S-1048	11/28	Fair	36	39	6	+ 5°R	+30°L	A2175	2443	45.24	54	8	46	85	37	63	0	0
								B2100	2355	45.24	52	8	44	85	38	62	0	0
	1909																	
S-1050	1/23	Fair	53	66	8	+ 0°	−25°R	1620	1618	40.44	40	16	24	60	75	25	0	0
S-1052	1/28	Wet	36	40	11	−45°L	+70°L	2430	1514	24.80	61	44	17	28	61	38	1	0
S-1057	3/6	Fair	34	40	10	+20°R	−35°L	1830	2107	41.32	51	8	43	84	49	43	6	2
S-1061	3/13	Fair	41	38	7	+45°L	−85°L	1785	2252	51.20	44	3	41	93	5	84	11	0
S-1063	3/19	Wet	39	40	12	+20°R	+40°R	3060	1484	20.04	74	70	4	5	7	93	0	0
S-1070	4/17	Fair	58	71	4	+ 0°	−65°L	2400	1622	24.60	66	49	17	26	58§	42	0	0
S-1072	5/1	Fair	35	37	17	+70°L	+90°L	1200	1859	66.40	28	1	27	96	4	96	0	0
S-1073	5/4	Fair	53	63	10	+25°L	+70°R	1200	1880	67.16	28	1	27	96	4	96	0	0
S-1074	5/7	Fair	45	60	10	+65°L	−80°L	3180	1340	16.56	81	81	0	0	2	98	0	0
S-1076	5/11	Fair	51	67	16	+40°R	+75°R	1120	1818	69.92	26	1	25	96	4	96	0	0
S-1077	5/14	Fair	64	70	13	−25°R	−75°R	2145	1505	28.40	53	35	18	34	74	26	0	0
S-1079	5/18	Fair	65	68	18	+65°R	−85°R	2070	1685	33.04	51	14	37	73	90	10	0	0
S-1080	5/21	Fair	50	70	11	+ 0°	+45°L	2550	1347	21.40	63	57	6	10	16	84	0	0

* Direction is designated by the angle made with the track. A wind any component of whose velocity helps the train forward is marked +; winds with components of opposing velocity are marked −. Winds from the right side of the track are designated as R; from the left side as L. Thus +40°R means a wind blowing from the rear and from the right hand side, whose direction makes an angle of 40 deg. with the track.

† All data apply to the train only—engine and tender are excluded. In Columns 9 to 19, for test S—1048, A indicates, from Champaign to Rantoul, B from Rantoul to Gilman.

‡ Train in Test S-1018 had two "dead" locomotives and tenders in addition to cars noted.

§ This number included 15 stock cars—classed as box.

station where levels were read to 0.01 ft. The results of the survey are expressed in a profile drawn to a scale of $\frac{1}{4}$ in. to 100 ft., which was used in making the test calculations.

36 *The Weather Conditions.* In Table 1 the weather prevailing during each test is designated as either fair or wet, wet weather meaning either continuous or intermittent rain. During seven of the thirty-two tests the weather was wet. The lowest air temperature recorded at any time during any test is 34 deg. fahr. and the highest recorded temperature is 82 deg.

37 The column headed "average wind velocity," in Table 1, presents the averages of the calculated wind velocities derived for each point or section of the test in question for which the train resistance was determined. There was a considerable variation at different points during the same test. The approximate maximum average velocity prevailing during any test was 25 miles per hour, the minimum 4 miles per hour. The actual wind direction (with respect to the track) varied during the tests, as would be expected, through the entire 360 degrees.

38 It was intended so to select the tests that the weather conditions, the temperatures, and the wind velocities, would be such as usually prevail in most parts of the country from the middle of spring until the middle of autumn when the basic or "summer" tonnage ratings are in force—such conditions, in short, as would give rise to no appreciable difficulties in train operation.

METHODS EMPLOYED IN CALCULATING THE RESULTS

39 The immediate purpose in making the calculations was to produce for each test a curve showing the relation between resistance and speed, for as great a variety of speeds as the data would permit. This involves calculating the train resistance at various positions of the train upon the track, and the first step is the inspection of the test-car record in order to select suitable points or sections at which the resistance may be calculated. The considerations of first importance are, that the points should finally represent as great a speed range as possible, and that the speeds should be approximately evenly distributed within this range. Only points and sections where the entire train was running and continued to run upon straight track, were selected; resistance due to track curvature is therefore entirely eliminated. The data essential to the process of calculation are the drawbar pull of the engine, the train speed and its acceleration, the ton-

nage, and the profile. The pull and the speed, as previously stated, were determined from continuous curves drawn on the test-car chart. Two processes were used, designated here as Method 1 and Method 2. By Method 1 the momentary values of pull, speed, acceleration, and grade, were determined for a particular position of the train upon the road; by Method 2 the average values of these quantities were determined for the period during which the test car was passing over a definite section of the track.

40 *Method 1, Resistance at a Point on the Road.* The point having been chosen, the pull and the speed were found by direct readings from the chart. This pull divided by the tonnage gives the gross train resistance at this speed. This gross resistance was next corrected for both acceleration and grade resistance. The acceleration was determined, by graphical methods from the speed curve, and the grade was found by correlating the train's position with the profile. The points were all so selected that at the moment under consideration, the entire train was on a nearly uniform grade. Method 1 results in momentary values of train resistance at the points considered.

41 *Method 2, Average Resistance over a Section.* By this method the average value of train resistance was determined for the period during which the test car at the head of the train was passing a selected section of the track. This track section, corresponding to a certain length or section on the test-car record, was so selected that the speed of the car when entering was nearly equal to its speed when leaving it; and further so that no considerable variations in speed occurred during transit over the section. The sections chosen have varied in length from about $\frac{1}{4}$ mile to 1 mile. The variations in speed in passing the section have generally amounted to less than 2.0 miles per hour, and the maximum variation over any selected section is 11.7 miles per hour. In only 58 cases out of a total of 560 does this speed variation exceed 5.0 miles per hour.

42 These portions of the chart being chosen, the average pull was next found by determining the average ordinate of the curve of drawbar pull, and the average speed was found by means of the section length and the time record. Gross resistance in pounds per ton was next derived by dividing this value of pull by the tonnage, and this gross resistance was then corrected for the resistances due to acceleration and grade as in Method 1.

43 In this case the average acceleration was found by consideration of the speeds at entrance to and exit from the section. In order

to correct for grade, the elevation of the center of gravity[1] of the train was determined for that position of the train at which the test car entered the section, and again for the position at which the car left the section. The difference between these elevations establishes the effective average grade, which either helps or opposes the locomotive while the train passes the section. These elevations of the center of gravity of the train may not be determined with sufficient accuracy unless the train at the moment, is on a practically uniform grade. The section limits were therefore so chosen.

44 Method 2 results in a value of *average* train resistance for the *average* speed at which the train passes the section under consideration. It would be rigidly correct if train resistance varied uniformly with speed, in other words, if the curve showing the relation of resistance to speed were a straight line. This, of course, is not the case, and the process therefore gives results which are slightly in error. However, as stated above, the section was so chosen that the difference between the speeds at entrance to and exit from the section was small; and for the speed range represented by this difference, the curve of train resistance deviates but little from a straight line. Such error as does result from the process is, therefore, very small and of no moment whatever when compared with the variations due to natural causes, that occur in the resistance itself.

45 *Comparison of the Two Methods.* The two methods are fundamentally alike. Although the first is the less laborious, it requires the determination of acceleration at a point on the speed curve; which it is sometimes difficult to make accurately. For this reason the second method is generally preferable. Method 2 also deals with average values and therefore tends to eliminate from the results the incidental momentary variations in resistance. Consequently the second method has been employed whenever possible, and the first method generally resorted to only in cases where the limitations imposed in the selection of sections for Method 2 would have resulted in too few values from which to plot the resistance curves. Of all the individual resistance values incorporated in the report only 32 per cent were determined by Method 1. The care exercised in the calculations, and a study of the plotted values obtained by both processes, seem to

[1] The location in the train of its center of gravity was determined thus: Assume a train which weighs 1800 tons, is 2400 ft. long, and is composed of 60 cars. By inspection of the tonnage record we find that one-half of this weight (900 tons) lies in the first 25 cars. Hence the center of gravity is located $\frac{25}{60}$ x 2400 = 1000 ft. from the front end.

warrant the conclusion that their results are equally reliable. In Fig. 1 the circles represent values derived by Method 1, and the circular black spots represent values obtained by Method 2.

46 *General Considerations.* Even in freight train operation the tractive effort required to produce acceleration in speed is frequently greater than that required to overcome all other resistances combined. To produce, for example, an acceleration of 0.1 miles per hour per sec., requires a tractive effort of about 9 lb. per ton, in addition to that required by net train resistance and grade resistance. Since the acceleration resistance may constitute so large a proportion of the gross resistance, it is important that its determination be made with great care. This fact has been impressed upon all concerned with these tests. In calculating the acceleration resistance, both the force required to produce acceleration in the rotation of the wheels and axles, and the force required to produce the acceleration in the motion of translation of the train as a whole, were determined.

47 The test-car records make it possible to distinguish those portions of each test where the brakes were applied. Such places, few in number, were of course avoided in selecting points and sections for determining resistance. The records also show where hot-boxes and unreleased brakes were discovered in the train, and such defects were given consideration in making the calculations. They occurred infrequently and their effect could not be distinguished in the results. While therefore such portions of the record were avoided if convenient, sections and points on the charts otherwise suitable for calculation, were not rejected on these accounts.

48 *Effect of Stops in Limiting the Selection of Points and Sections.* Early in the progress of this work, when low air temperatures were first encountered, it became apparent that when the train was first started from rest, its resistance, calculated for a number of points at which the speed was the same, occasionally was unusually high. This was true not only for those portions of the run made immediately after leaving the yards; but also for those portions immediately following stops on the road. In a certain test, for example, the values of net resistance, calculated at various points at all of which the speed was 20 miles per hour, varied between 6.8 lb. and 5 lb. per ton—a difference of 27 per cent—for points selected within the first 9 miles of the run; whereas values of resistance at the same speed, determined later in the test, differed by only 10 per cent. The air temperature during this test (not included in the report) varied between 22 deg. and 26 deg.

49 For a number of tests such resistance values were plotted with respect to the distances from the yards of the points to which they apply. This process disclosed a surprisingly regular decrease in the resistance, until a distance of approximately ten miles was reached, after which the resistance had settled down to a fairly uniform value. Similar variations were found to occur to some extent during tests when the air temperature was as high as fifty or sixty degrees. This study[1] led to the conclusion that the difference in resistance was due to variations in the conditions of lubrication of the car journals, and that such variations were chiefly caused by changes in journal temperature. All this is, of course, in accord with the common belief of those experienced in train operation. The reason for discussing it in this place is that the facts stated have influenced the procedure in making calculations for this series of tests.

50 Since the variations in resistance are so great during the early part of the run no point or section within about the first ten miles has been selected for calculation in any test. If other points or sections, located farther from the start, were near stops, such points were rejected unless further investigation proved that at these places the train resistance had become nearly uniform in value. Fortunately operating conditions were such as to entail few stops, and the selection of points and sections for the calculations has not been unduly limited on these accounts.[2]

51 The effect of these limitations is to make the results of this investigation primarily applicable to trains which have been for some time in motion. Since, however, stops are not usually made upon ruling grades; and since if stops are made at other places on the road, the locomotive has available tractive power in excess of the requirements, the results of these tests are generally applicable in the solution of tonnage rating problems, except where the ruling grade occurs near a yard or other point where the trains are made up. In such cases the tonnage determined from the resistance curves here presented may prove to be somewhat too great.

52 *The Derivation of the Resistance Curves.* The calculations

[1] Further investigation of this matter is in progress, and the results are likely soon to be published.

[2] During the thirty-two tests included in the investigation, only sixty-eight stops, all told, were made after leaving the yards. Of these, one was of 55 minutes duration, nine lasted between 20 and 40 minutes, twenty-two between 10 and 20 minutes, and thirty-six less than 10 minutes.

result, for each test, in a series of values of net train resistance at a variety of speeds. These values of resistance were plotted with respect to speed, and gave such a diagram as is shown in Fig. 1. The curve, such as is there shown, was next drawn to express, for the test in question, the relation existing between resistance and speed. In order to draw this curve, the plotted points were assumed to be arranged in a number of groups, and for each group the averages of the values of speed and of resistance were determined. By these averages a new point or "center of gravity" of the group was then plotted. The curve was drawn by confining attention to the few points thus determined. The groups of points were arbitrarily selected so that the resulting "centers of gravity" would be nearly equidistantly distributed throughout the speed range. All curves presented in the report, except those exhibited in Fig. 11, were drawn by this process.

53 All reasonable precautions have been taken to attain accuracy in the calculations. In determining each value of resistance, each step was duplicated at a different time, and generally by a different person. The transcription of all tables, the plotting of points and the drawing of curves, have been similary checked.

RESULTS OF THE TESTS

54 *Results of the Individual Tests.* The immediate result of each test is a curve which shows for the train under consideration, the relation existing between train resistance and speed. Fig. 1 is such a curve derived from test S-1021. It is fairly representative of the entire group of curves, and such discussion of it as follows is general in its application.

55 · The plotted points show unmistakably an increase in resistance as the speed increases, and the curve drawn represents the mean relation between resistance and speed. In Fig. 1 the maximum variation from this mean of any calculated value of resistance is about 20 per cent; the next largest variation is 16 per cent, and other calculated values of resistance generally differ from the values determined from the curve by less than 10 per cent. In a majority of the tests the maximum variation is less than in Fig. 1, and the general agreement between the calculated values of resistance and the ordinates of the curve is better than in the test chosen for illustration.

56 It has been thought desirable to express more specifically this variation between the calculated values of resistance and the mean values as derived from the curves drawn. To this end, for all tests,

all calculated values of resistance for speeds between 8 and 12 miles per hour were compared with the ordinates of the curves at the corresponding speeds, and the percentage difference was determined in each case. These percentages were then arranged in two groups and averaged. The one group included the results from all points lying above the curve, the other from those lying below it. The whole process was next repeated for speeds between 28 and 32 miles per hour, with results as follows:

Average Deviation (for all tests) of Calculated Resistance from the Mean Values Derived from the Curves, Expressed in Percentage of the Mean Values.

Speed	Above the Mean	Below the Mean
8 to 12 m.p.h.	6.4 per cent	7.6 per cent
28 to 32 m.p.h.	5.6 per cent	6.6 per cent

Such variation seems not extraordinary for this class of experimental work.

57 These differences may be due in part to accumulated errors in the instruments or in the calculations. In all cases, however, where the calculated value of resistance varied by an unusual amount from the mean, all calculations leading thereto were repeated and errors thus discovered are eliminated from the report. The explanation for such differences need not be sought further than in the variations which actually occur from time to time, in the resistance itself. Variations in such components of train resistance as flange friction and wind resistance are probably sufficiently great to account for the differences discussed above. The data do not permit the influences of such components of resistance to be differentiated.

58 The curve drawn for each test has been accepted as representing the average values of net train resistance, with a degree of accuracy sufficient for the purpose of rating locomotives. Such temporary excess of resistance as may be expected to occur will generally be absorbed in that reserve in the tractive effort of the locomotive which must be allowed in any system of tonnage rating.

59 *Results of all the Tests.* The resistance curves for the individual tests have all been brought together on one sheet, a reproduction of which is shown as Fig. 2.* Fig. 2 displays the immediate results

* The numbers shown on the curves are the last two figures of the test numbers. The curve marked 43 is derived from Test S-1043.

of the whole research. The lower curves give values of resistance varying from 3 to 5½ lb. per ton, while the upper curves show resistance values varying from 7 to 14 lb. per ton. Resistance values at the lower speeds differ by 100 per cent, and values at higher speeds differ by as much as 200 per cent.

60 If further analysis had not revealed the cause of the great variation in resistance here shown, Fig. 2* would have remained a useless exhibit. The explanation of this variation was sought in the test conditions enumerated below:

a Weather and temperature conditions.
b Wind velocity and direction.
c Kind of cars composing the train.
d Position of the loaded cars in the train.
e Defects in train equipment.
f Average weight of the cars in the train.

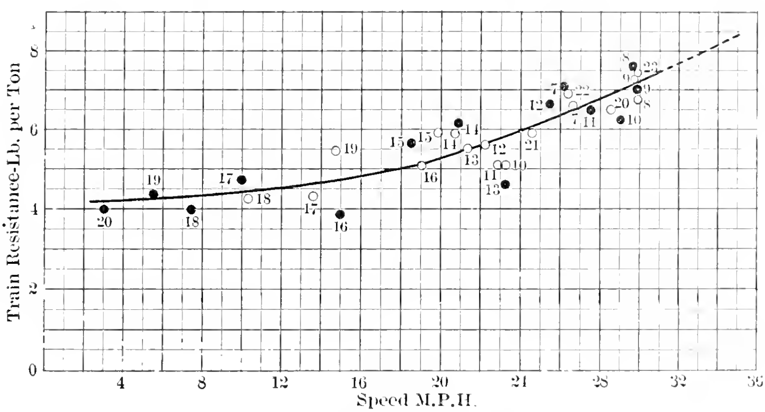

FIG. 1. RELATION OF RESISTANCE TO SPEED FOR TEST S-1021
AVERAGE WEIGHT PER CAR 46.16 TONS

61 The first five conditions either are uncontrollable or purposely were not controlled during these experiments, and attempts to explain the differences by reference to one or the other of them have been altogether unsuccessful. While difference in wind velocity, for example, might be a plausible explanation of the differences between two or

* Table 2 has been prepared from the original curves of the individual tests, only one of which is separately presented in the report (see Fig. 1). It gives no information not obtainable from Fig. 2; but presents the information in more convenient form, since the number of curves drawn in the figure makes it confusing.

three curves selected at random from Fig. 2, such explanation will not hold when applied to two or three other curves similarly chosen; and it fails altogether to explain such differences when it is applied to the whole group. The same remarks apply to any other of the first five items.

62 Item *f*, however, has furnished the clue whereby the apparent confusion in the results of the tests, as exhibited in Fig. 2, has been explained. It may be stated at once that the difference in train resistance for various tests is believed to be chiefly due to differences in the average gross car weights existing during the tests. An explanation of the process which led to this opinion follows immediately below. As was stated at the outset, this conclusion was anticipated when the work was begun, and the average car weight was therefore controlled during the experiments, and made to vary through the widest possible range.

63 *The Effects of Car Weight on Resistance.* The four upper curves of Fig. 2 are derived from trains in which the average weight per car was about 16 or 17 tons. The lowest curves are those derived from trains in which the car weight was nearly 70 tons. These facts serve as a rough indication of the part played by car weight in effecting changes in train resistance. This influence is more definitely brought out in the following discussion.

64 If from each of the curves of Fig. 2 the value of resistance is determined at one speed, say 5 miles per hour, these values of resistance may then be plotted with respect to their corresponding values of car weight; and since the speed is common, its influence is eliminated and the resulting diagram may be expected to reveal the relation existing between train resistance and average weight per car. Table 2 was prepared to facilitate this process. In it the tests are arranged in the order of the average car weights, which are given in the second column, and in the succeeding columns are set down the resistance values obtained from the *curves* of the individual tests, for each of seven different speeds. Table 2 therefore presents the values of the coördinates of seven points on each of the curves of Fig. 2, and hence, like Fig. 2, summarizes the immediate results of all tests.

65 In Table 2 the second and third columns present a series of values of average car weight and of train resistance at 5 miles per hour. Each pair of values represents the results of one of the 32 tests. Using these pairs of values as coördinates, a series of points has been plotted to form a new diagram, Fig. 3. For example, the point marked 21 in Fig. 3 is derived from the curve of Test S-1021.

The curve of resistance for this test (see Fig. 1 or Fig. 2) shows that at 5 miles per hour the mean resistance is 4.21 lb. per ton. During this test the average weight of the cars in the train was 46.16 tons. Table 2 also exhibits both of these values which, when plotted in Fig. 3, determine the point there marked 21. The other points of Fig. 3 were similarly determined. Each point represents the value of resistance at 5 miles per hour, derived from a particular test train.

66 Although there is considerable variation among the points of Fig. 3, they indicate clearly a decrease in the resistance as the car weight increases. The curve drawn in Fig. 3 represents, for the trains tested, the mean relation which existed, between resistance at 5 miles per hour and the average car weight.[1] For higher speeds this relation between resistance and car weight is shown by Figs. 4 to 9, which were derived by the same methods employed in producing Fig. 3.

67 The variation in resistance represented by the points in Figs. 3 to 9 is sufficient to warrant further discussion. Such discussion will, however, be postponed until later in the report. The conclusion reached is that these variations are largely caused by factors which are uncontrollable in ordinary train operation. If this be admitted, it is clear that the discussion of such variations may enter into the solution of tonnage rating problems, only as an argument for reserve tractive effort in the locomotive. An estimate of the desirable amount of such reserve appears beyond.

68 The curves of Figs. 3 to 9 have been accepted as representing, for these tests, the mean relation which existed betwe entrain resistance and the average gross weight of the cars composing the trains. These curves exhibit this relation at seven different speeds, 5, 10, 15. 20, 25, 30, and 35 miles per hour. For convenience in use, and to make comparison easier, these seven curves have been brought together in one diagram which is reproduced in Fig. 10.

69 Fig. 10 presents the final results of the whole research. Each of the curves there drawn shows the mean relation which existed during the tests, between car weight and resistance at a definite speed. It is believed that the curves of Fig.10 are generally applicable to ordinary American freight trains, provided the conditions surrounding their operation are like those which prevailed during these tests.

[1] As has been previously explained, the curve is drawn by finding the "center of gravity" of several groups of points. These centers are defined in Figs. 3 to 9 by the crosses within circles. Points 34 and 74 were virtually ignored in drawing the curves of Figs. 6 and 7. The numbers at the points are the last two figures of the test numbers.

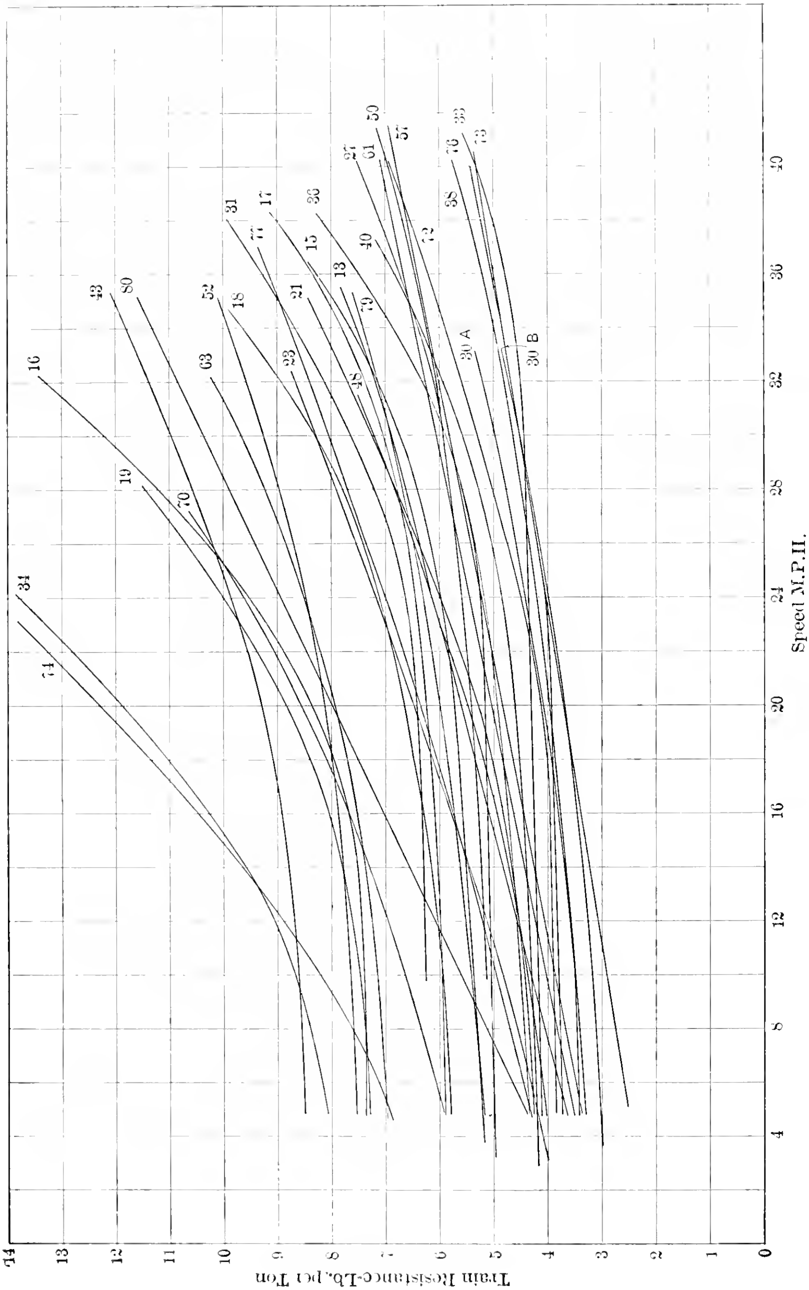

FIG. 2. CURVES SHOWING RELATION BETWEEN RESISTANCE AND SPEED FOR EACH OF THE 32 TESTS

TABLE 2 RESISTANCE AT VARIOUS SPEEDS

DERIVED FROM THE CURVES FOR THE INDIVIDUAL TESTS. THIS TABLE PROVIDES THE COÖRDINATES OF THE POINTS PLOTTED IN FIGS. 3 TO 9

Test No.	Average Weight per Car Tons	Train Resistance—Pounds per Ton						
		5 m.p.h.	10 m.p.h.	15 m.p.h.	20 m.p.h.	25 m.p.h.	30 m.p.h.	35 m.p.h.
S-1016	16.12	7.35	7.40	7.62	8.37	9.91	12.22	.....
S-1034	16.56	8.10	8.70	9.92	11.90	14.30	.....	.....
S-1074	16.56	6.92	8.23	10.10	12.32	14.70	.....	
S-1043	16.92	8.50	8.61	8.85	9.30	10.00	10.95	12.04
S-1019	17.72	7.30	7.47	7.90	8.85	10.32	.....	.....
S-1063	20.04	6.98	7.13	7.43	7.90	8.63	9.63	....
S-1031	20.72	....	6.24	6.30	6.40	6.73	7.60	8.94
S-1080	21.40	4.40	5.57	6.75	7.94	9.15	10.35	11.55
S-1070	24.60	5.93	6.63	7.47	8.57	9.90	.....	.....
S-1052	24.80	7.55	7.63	7.80	8.10	8.55	9.20	10.05
S-1018	25.40	5.80	5.95	6.20	6.63	7.22	8.26	10.02
S-1077	28.40	4.32	4.91	5.58	6.34	7.15	8.01	8.96
S-1079	33.04	3.66	4.30	4.92	5.60	6.22	6.89	7.55
S-1015	36.08	5.20	5.36	5.52	5.70	6.02	6.71	7.95
S-1036	37.72	4.98	5.03	5.12	5.15	5.31	5.88	7.15
S-1013	38.04	....	5.40	5.65	5.95	6.32	6.90	7.68
S-1017	38.44	5.90	5.95	6.02	6.20	6.48	7.01	8.03
S-1023	38.72	4.16	4.80	5.56	6.40	7.30	8.25	....
S-1050	40.44	....	5.10	5.25	5.40	5.62	5.90	6.33
S-1057	41.32	3.40	3.88	4.35	4.83	5.31	5.80	6.30
S-1048	45.24	4.05	4.35	4.80	5.48	6.30	7.23	....
S-1040	45.76	4.22	4.30	4.40	4.58	4.90	5.52	6.53
S-1021	46.08	4.21	4.41	4.72	5.29	6.15	7.20	8.40
S-1027	47.44	4.31	4.48	4.67	4.90	5.22	5.79	6.55
S-1061	51.20	3.50	4.00	4.51	5.01	5.51	6.01	6.53
S-1033	51.72	4.10	4.15	4.20	4.25	4.32	4.40	4.65
S-1038	52.28	3.30	3.50	3.71	3.95	4.25	4.60	5.08
S-1030B	57.12	3.73	3.80	3.82	3.90	4.10	4.50	....
S-1030A	59.88	3.84	3.88	3.92	4.10	4.45	4.95	....
S-1072	66.40	3.40	3.50	3.70	4.10	4.61	5.27	6.00
S-1073	67.16	2.52	2.90	3.30	3.70	4.10	4.50	4.90
S-1076	69.92	2.97	3.13	3.37	3.70	4.04	4.49	4.95

The curves of Fig. 10 enable one to determine the probable mean resistance of any such train, at speeds between 5 and 35 miles per hour, provided the average weight of the cars composing the train be known.

70 *The Results Expressed as Resistance-Speed Curves.* While Fig. 10 presents the main results of the experiments, the form in which these results are there expressed is unusual. Ordinarily train resist-

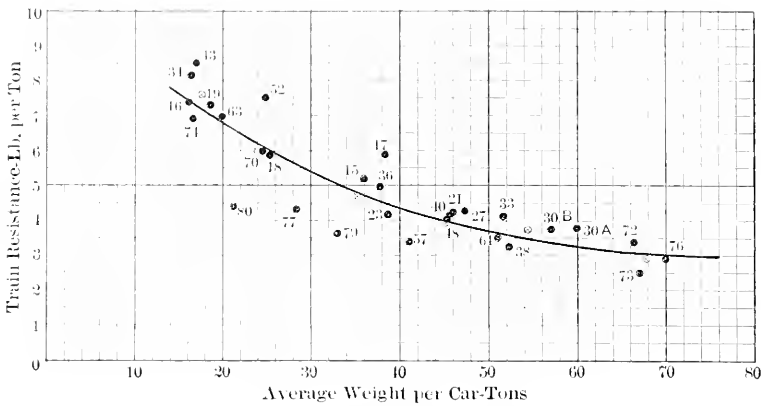

FIG. 3 RELATION BETWEEN RESISTANCE AND AVERAGE CAR WEIGHT
SPEED 5 MILES PER HOUR

ance is expressed either as a curve or equation which defines the relation between resistance and speed, instead of the relation between resistance and car weight as in Fig. 10. Obviously to express the results of these experiments in the usual form a single curve will not

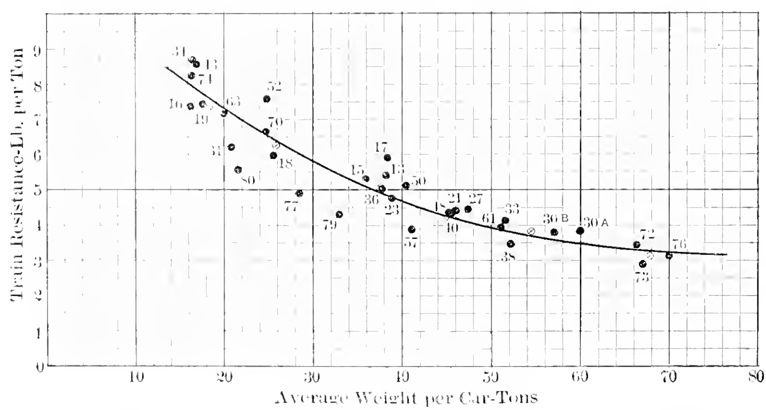

FIG. 4 RELATION BETWEEN RESISTANCE AND AVERAGE CAR WEIGHT
SPEED 10 MILES PER HOUR

suffice, since the influence of car weight cannot be thereby made evident. A number of curves will be required for this purpose, each of which will apply only to a definite average car weight. Fig. 11 presents such a group of resistance-speed curves, which have been

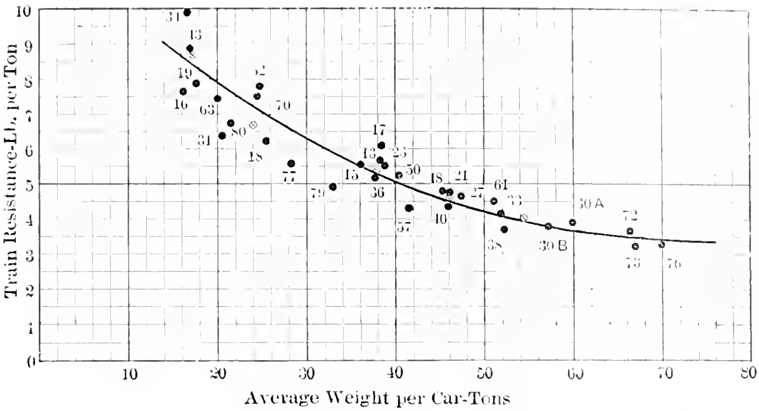

FIG. 5 RELATION BETWEEN RESISTANCE AND AVERAGE CAR WEIGHT

SPEED 15 MILES PER HOUR

derived directly from the curves of Fig. 10. Fig. 11 therefore exhibits in different form only such information as is obtainable from Fig. 10.

71 The relation between the two figures may be made clear by explaining the derivation of the upper curve in Fig. 11, the one apply-

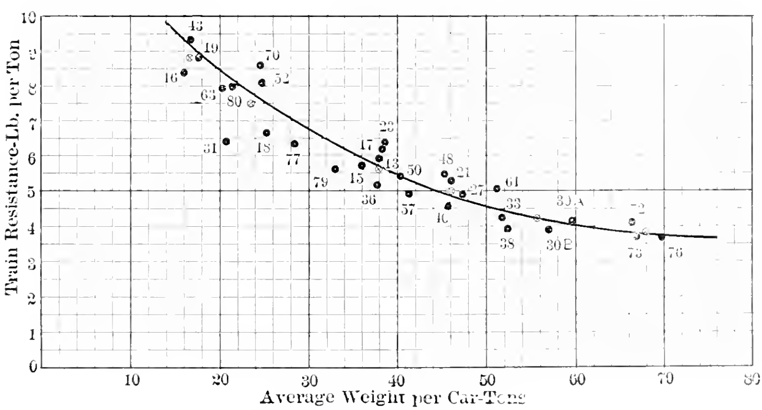

FIG. 6 RELATION BETWEEN RESISTANCE AND AVERAGE CAR WEIGHT

SPEED 20 MILES PER HOUR

ing to a car weight of 15 tons. In Fig. 10 the ordinate corresponding to an average car weight of 15 tons cuts the seven curves there drawn at seven points, at which the mean resistance values are 7.62, 8.20, 8.81, 9.56, 10.37, 11.24 and 12.25 lb. per ton, corresponding to

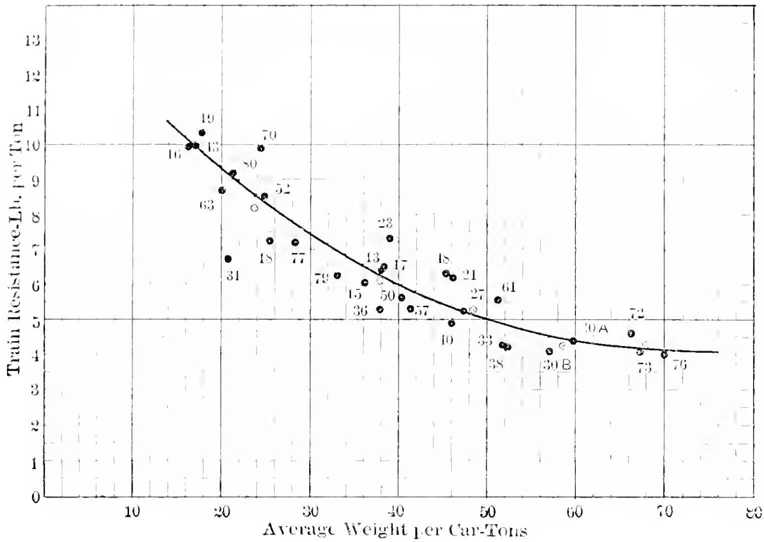

FIG. 7 RELATION BETWEEN RESISTANCE AND AVERAGE CAR WEIGHT

SPEED 25 MILES PER HOUR

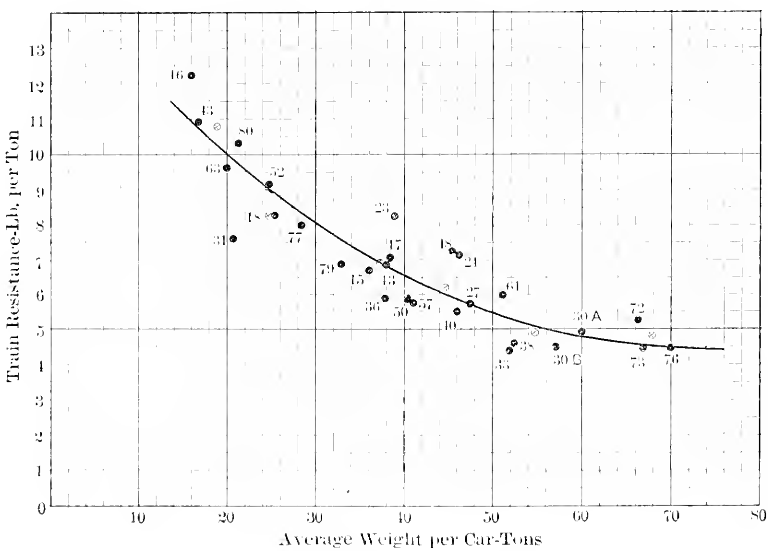

FIG. 8 RELATION BETWEEN RESISTANCE AND AVERAGE CAR WEIGHT

SPEED 30 MILES PER HOUR

speeds of 5, 10, 15, 20, 25, 30 and 35 miles per hour respectively These values are the coördinates of seven points on a resistance-speed curve applying to a car weight of 15 tons. These seven points have been plotted in Fig. 11, and the upper curve there shown has been passed through them and extended to 40 miles per hour. The other curves of Fig. 11 were derived by a like process. In the original diagram three additional curves, corresponding to 55, 65 and 70 tons per car, were drawn. These three curves have been omitted from the figure to avoid confusion. Fig. 11 reproduces quite exactly the facts presented in Fig. 10;* and presents the final results of the experiments.

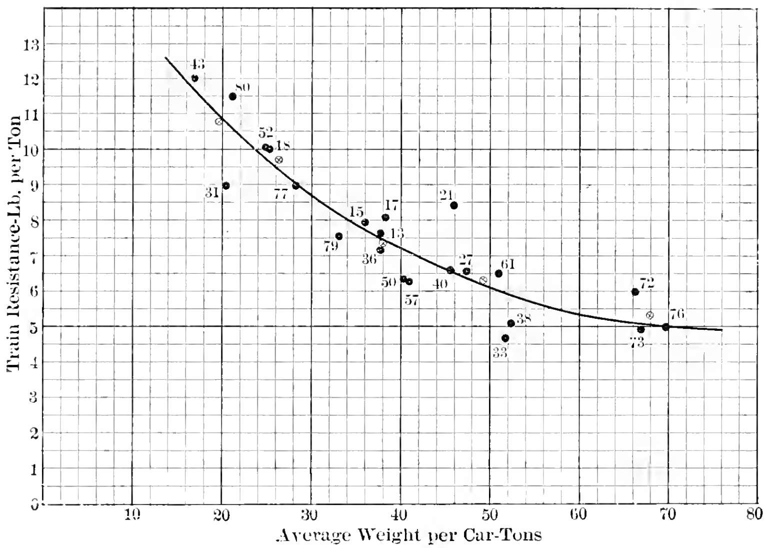

Fig. 9 Relation between Resistance and Average Car Weight
SPEED 35 MILES PER HOUR

72 *The Results Expressed in Tabular Form.* From each of the curves of Fig. 11 the values of resistance at various speeds have been determined and set down in Table 3. Table 3 also includes the coördinates of the resistance curves corresponding to 55, 65 and 70 tons per car, which are omitted from Fig. 11.

*The points derived from Fig. 10 have been omitted from the tracing from which Fig. 11 was reproduced. All such points lie very close to the curves drawn in Fig. 11, the maximum deviation amounting to but ¾ of one per cent of the corresponding curve ordinate. In the Appendix there are presented tables of coördinates, by means of which Figs. 10 and 11 may be exactly reproduced.

73 *The Results Expressed as Equations.* The relation between resistance and speed shown by each of the curves of Fig. 11 may be also expressed in the form of an equation. Formulæ 1 to 13 below are such equations, by means of which resistance may be calculated for any speed and for various car weights. In the formulæ, R is the resistance expressed in pounds per ton, S is the speed expressed in miles per hour, and W is the average weight of the cars in the train expressed in tons. The formulæ are purely empirical, and are simply equations of parabolas so selected as to correspond very closely with the curves of Fig. 11. The correspondence between the formulæ and

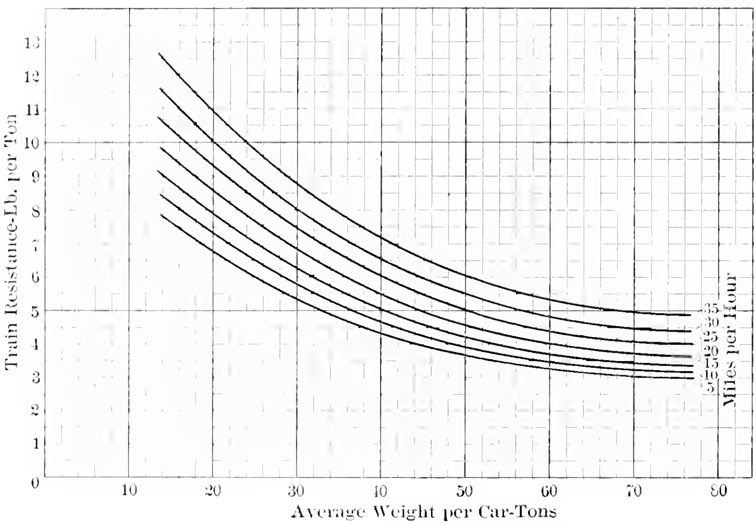

FIG. 10 RELATION BETWEEN RESISTANCE AND AVERAGE CAR WEIGHT AT VARIOUS SPEEDS

the curves is such that the maximum difference between any value of resistance obtained by the formulæ, and the corresponding value obtained from the curves of Fig. 11, is $\frac{1}{2}$ of one per cent. Since these are empirical equations their use should not be extended beyond the speed limits shown on Fig. 11.

74 It is possible to express approximately the facts presented in Fig. 11, in a single equation which includes only the first power of the three variables, R, S and W. Such an equation would obviously be more convenient than the group given below. Several such equations have been derived, each of which well represents, in general,

the results of the tests. Each of them, however, at some points in its range of application, leads to errors as great as 10 per cent. It has been deemed inadvisable to publish a formula containing so great an initial error.

75 *Final Results.* The final results of the research are presented in Fig. 11, in Table 3, and in Formulæ 1 to 13. It is believed that by means of either the figure, the table, or the formulæ, the resistance of ordinary freight trains may be fairly accurately predicted; provided the conditions surrounding their operation are similar to those which prevailed during these tests. These conditions have been fully stated and are restated in the conclusions. It is sufficient to repeat at this point that the results apply to trains running at uniform speed, on tangent and level track of good construction, during weather when the temperature is not lower than 30 deg. fahr. and when the wind velocity does not exceed about 20 miles per hour.

TRAIN RESISTANCE FORMULÆ

When $W = 15$ tons; $R = 7.15 + 0.085\ S + 0.00175\ S^2$ . . (1)
" $W = 20$ " $R = 6.30 + 0.087\ S + 0.00126\ S^2$ . . (2)
" $W = 25$ " $R = 5.60 + 0.077\ S + 0.00116\ S^2$ . . (3)
" $W = 30$ " $R = 5.02 + 0.066\ S + 0.00116\ S^2$ . . (4)
" $W = 35$ " $R = 4.49 + 0.060\ S + 0.00108\ S^2$ . . (5)
" $W = 40$ " $R = 4.15 + 0.041\ S + 0.00134\ S^2$ . . (6)
" $W = 45$ " $R = 3.82 + 0.031\ S + 0.00140\ S^2$ . . (7)
" $W = 50$ " $R = 3.56 + 0.024\ S + 0.00140\ S^2$ . . (8)
" $W = 55$ " $R = 3.38 + 0.016\ S + 0.00142\ S^2$ . . (9)
" $W = 60$ " $R = 3.19 + 0.016\ S + 0.00132\ S^2$ . . (10)
" $W = 65$ " $R = 3.06 + 0.014\ S + 0.00130\ S^2$ . . (11)
" $W = 70$ " $R = 2.92 + 0.021\ S + 0.00111\ S^2$ . . (12)
" $W = 75$ " $R = 2.87 + 0.019\ S + 0.00113\ S^2$ . . (13)

DISCUSSION OF THE RESULTS

76 *Variations in Resistance of Different Trains.* Reference has previously been made to the variations among the points of Figs. 3 to 9. In each figure about one-half of the points lie above the curve there drawn, and their resistance values vary from those of the curve by different amounts. It should be borne in mind that, in these figures each point represents the average resistance which prevailed throughout a particular test, and differences among the points represent, therefore, differences in the mean resistance of the different trains.

77 Among those trains which are regarded as normal there are two or three whose resistance at some speed varies from the mean, as expressed in the curves, by as much as 23 per cent. The great major-

ity, however, vary from this mean by about 10 per cent or less. In Fig. 4, for example, there are nineteen points which lie above the curve, among which the maximum deviation from the mean is 23 per

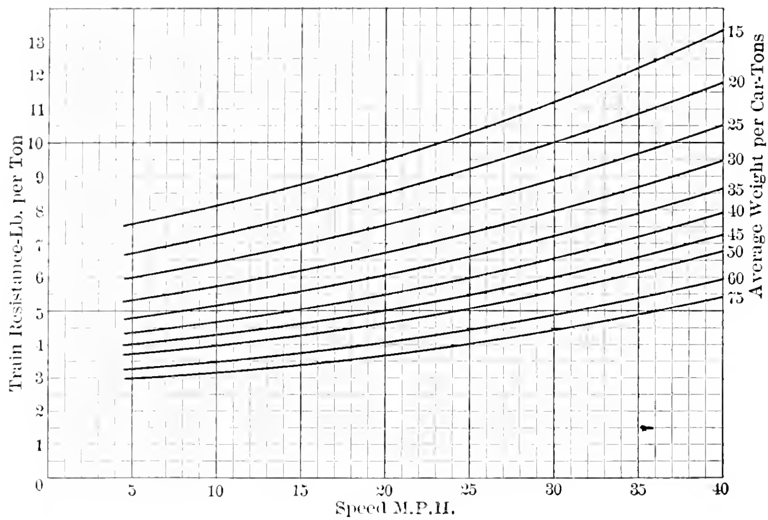

FIG. 11 RELATION BETWEEN RESISTANCE AND SPEED FOR VARIOUS AVERAGE WEIGHTS PER CAR

cent, while the average of the deviation for all nineteen points is 8 per cent. The following table presents similar average deviations above and below the mean for each of Figs. 3 to 9.

AVERAGE DEVIATION OF ALL POINTS IN FIGS. 3 TO 9, FROM THE MEAN AS SHOWN BY THE CURVES THERE DRAWN, EXPRESSED AS PERCENTAGES OF THE CURVE ORDINATES.

	Fig. 3 5 m.p.h.	Fig. 4 10 m.p.h.	Fig. 5 15 m.p.h.	Fig. 6 20 m.p.h.	Fig. 7 25 m.p.h.	Fig. 8 30 m.p.h.	Fig. 9 35 m.p.h.
Points above the curve...	11	8	8	11	13	8	7
Points below the curve..	13	10	9	8	9	9	9

78 The data present no satisfactory general explanation for these differences in the resistance of different trains of like average weight per car. They may be due to difference in external conditions, or in train condition and make-up. Whatever the explanation it is

TABLE 3 RESISTANCE AT DIFFERENT SPEEDS AND FOR TRAINS OF VARIOUS AVERAGE CAR WEIGHTS

THE VALUES ARE DERIVED DIRECTLY FROM THE CURVES OF FIG. 11 AND REPRESENT THE FINAL RESULTS OF THE TESTS

Speed Miles per Hour	Train Resistance—Pounds per Ton (column headings indicate the average car weights)													Speed Miles per Hour
	15 tons	20 tons	25 tons	30 tons	35 tons	40 tons	45 tons	50 tons	55 tons	60 tons	65 tons	70 tons	75 tons	
5	7.6	6.8	6.0	5.4	4.8	4.4	4.0	3.7	3.5	3.3	3.2	3.1	3.0	5
6	7.7	6.9	6.1	5.5	4.9	4.4	4.1	3.8	3.5	3.3	3.2	3.1	3.0	6
7	7.8	7.0	6.2	5.5	5.0	4.5	4.1	3.8	3.6	3.4	3.2	3.1	3.1	7
8	8.0	7.1	6.3	5.6	5.0	4.6	4.2	3.9	3.6	3.4	3.3	3.2	3.1	8
9	8.1	7.2	6.4	5.7	5.1	4.6	4.2	3.9	3.6	3.4	3.3	3.2	3.1	9
10	8.2	7.3	6.5	5.8	5.2	4.7	4.3	4.0	3.7	3.5	3.3	3.2	3.2	10
11	8.3	7.4	6.6	5.9	5.3	4.8	4.3	4.0	3.7	3.5	3.4	3.3	3.2	11
12	8.4	7.5	6.7	6.0	5.4	4.8	4.4	4.0	3.8	3.6	3.4	3.3	3.3	12
13	8.6	7.6	6.8	6.1	5.5	4.9	4.5	4.1	3.8	3.6	3.5	3.4	3.3	13
14	8.7	7.8	6.9	6.2	5.5	5.0	4.5	4.2	3.9	3.7	3.5	3.4	3.4	14
15	8.8	7.9	7.0	6.3	5.6	5.1	4.6	4.2	3.9	3.7	3.6	3.5	3.4	15
16	9.0	8.0	7.1	6.4	5.7	5.1	4.7	4.3	4.0	3.8	3.6	3.5	3.5	16
17	9.1	8.1	7.2	6.5	5.8	5.2	4.8	4.4	4.1	3.9	3.7	3.6	3.5	17
18	9.3	8.3	7.4	6.6	5.9	5.3	4.8	4.5	4.1	3.9	3.7	3.7	3.6	18
19	9.4	8.4	7.5	6.7	6.0	5.4	4.9	4.5	4.2	4.0	3.8	3.7	3.6	19
20	9.6	8.5	7.6	6.8	6.1	5.5	5.0	4.6	4.3	4.0	3.9	3.8	3.7	20
21	9.7	8.7	7.7	6.9	6.2	5.6	5.1	4.7	4.3	4.1	3.9	3.9	3.8	21
22	9.9	8.8	7.9	7.0	6.3	5.7	5.2	4.8	4.4	4.2	4.0	3.9	3.8	22
23	10.0	9.0	8.0	7.1	6.4	5.8	5.3	4.9	4.5	4.3	4.1	4.0	3.9	23
24	10.2	9.1	8.1	7.3	6.6	5.9	5.4	4.9	4.6	4.3	4.2	4.1	4.0	24
25	10.4	9.3	8.3	7.4	6.7	6.0	5.5	5.0	4.7	4.4	4.2	4.1	4.0	25
26	10.5	9.4	8.4	7.5	6.8	6.1	5.6	5.1	4.8	4.5	4.3	4.2	4.1	26
27	10.7	9.6	8.5	7.7	6.9	6.2	5.7	5.2	4.8	4.6	4.4	4.3	4.2	27
28	10.9	9.7	8.7	7.8	7.0	6.3	5.8	5.3	4.9	4.7	4.5	4.4	4.3	28
29	11.1	9.9	8.8	7.9	7.1	6.5	5.9	5.4	5.0	4.8	4.6	4.5	4.4	29
30	11.3	10.0	9.0	8.0	7.3	6.6	6.0	5.5	5.1	4.9	4.7	4.5	4.5	30
31	11.4	10.2	9.1	8.2	7.4	6.7	6.1	5.6	5.2	5.0	4.8	4.6	4.5	31
32	11.6	10.4	9.3	8.3	7.5	6.8	6.2	5.8	5.3	5.0	4.9	4.7	4.6	32
33	11.8	10.5	9.4	8.5	7.6	7.0	6.3	5.9	5.4	5.2	5.0	4.8	4.7	33
34	12.0	10.7	9.6	8.6	7.8	7.1	6.5	6.0	5.5	5.3	5.1	4.9	4.8	34
35	12.3	10.9	9.7	8.8	7.9	7.2	6.6	6.1	5.7	5.4	5.2	5.0	4.9	35
36	12.5	11.1	9.9	8.9	8.0	7.4	6.7	6.2	5.8	5.5	5.3	5.1	5.0	36
37	12.7	11.2	10.0	9.0	8.2	7.5	6.9	6.4	5.9	5.6	5.4	5.2	5.1	37
38	12.9	11.4	10.2	9.2	8.3	7.6	7.0	6.5	6.0	5.7	5.5	5.3	5.2	38
39	13.1	11.6	10.4	9.4	8.5	7.8	7.1	6.6	6.2	5.8	5.6	5.4	5.3	39
40	13.4	11.8	10.6	9.5	8.6	7.9	7.3	6.8	6.3	6.0	5.7	5.6	5.5	40

significant that about one-half of the trains experimented upon developed a resistance about 9 per cent in excess of the mean resistance which would be predicted by the use of Figs. 3 to 9 and Figs. 10 and 11. Obviously a similar excess may be expected with any train; it is suggested therefore that in determining the resistance of trains on *level tangent track* for the purpose of rating locomotives under operating conditions which demand conservative ratings, 9 per cent be added to the resistance values obtained from the curves, tables and equations presented. Such considerations are of little practical importance in rating locomotives for speeds above 15 miles per hour. In such cases an excess in resistance over that expected can result in nothing more serious than failure to realize the expected train speed.

79 It should be understood that this 9 per cent allowance is intended to cover probable variations in the resistance of different trains under normal operating conditions. It in no way takes the place of that additional reserve which must be allowed to cover unusual variations in resistance due to low temperatures or high winds, nor of that reserve in the tractive effort of the locomotive necessitated by operating conditions which reduce the efficiency of the locomotive itself.

80 *Tests which Present Abnormal Resistance Values.* There are four points in Figs. 3 to 9 whose deviation from the curves is so great as to demand special examination. These are the points corresponding to Tests S-1034, S-1074, S-1080, and S-1031 (points 34, 74, 80, and 31). These tests show a persistent and great variation from the mean at various speeds. The trains of Tests 1034, 1074, and 1080 were like in average car weights, less than 23 tons, and in containing a large proportion of empty gondolas— 99, 98, and 84 per cent, respectively. Any explanation based on train composition is however nullified by the fact that the trains of Tests 1016, 1043, and 1063, which show close correspondence with the curves, had similar average car weights and contained almost equally large proportions of empty gondolas. Weather and wind conditions likewise offer no explanation of the divergences presented by these three tests. Explanations are rendered more difficult by the fact that while the trains of Tests 1034 and 1074 show unusually high resistance, the resistance in Test 1080 is exceptionally low. The abnormalities presented by these three trains have therefore been accepted as unexplained by the data at hand.

81 The resistance of the train of the fourth test mentioned above (S-1031) was low at all speeds. This train had an average car weight

of 20.7 tons, contained 94 per cent of box cars, and was only 1425 ft. long. Other test trains of similar average car weight differ generally in having less than 60 per cent of box cars, and all in being 2400 ft. or more in length. Taking into consideration all the data, neither fact seems to offer an adequate explanation, however, of the variations exhibited by this train.

82 *Car Weight as a Basis of Expression.* Objection may be made to the form of expression adopted in Figs. 3 to 9 and in Fig. 10, in which the resistance is expressed solely in terms of average car weight, to the apparent neglect of the influence of those elements of resistance, such as air resistance, which are independent of weight, and which probably vary only with the number of cars in the train. The neglect is only apparent, however, for the process by which Fig. 10 was derived involves, although indirectly, recognition of the influence of the number of cars. It is quite likely that if Fig. 10 were applied to determine the total resistance of a single car, the result would be in error.

83 Whatever objection may be urged against the form of expression adopted, it remains true that Fig. 10 rests upon experimental results obtained with trains of usual length and that in practice one is not likely to encounter trains which present in this respect any extreme variation from the test data. The form of expression will not lead to error unless misapplied, and it was chosen because the results may be conveniently used in establishing tonnage ratings.

84 It might likewise have been more rational to express the resistance in terms of load per axle instead of load per car, since the latter can operate to cause variations in resistance only in so far as it affects the former. Since, however, all American freight cars have four axles, the expression in either form would be identical. Convenience in application warrants the choice made in this respect also.

85 *Effect of Variety in Car Weight upon Total Train Resistance.* In Fig. 10 those portions of the curves which apply to average car weights below 20 tons were derived from trains which were quite homogeneous in their make-up as regards weight per car. These trains were necessarily composed almost exclusively of empty cars, since an average car weight of 20 tons or less cannot otherwise be obtained with cars of current design; and being empty they will be uniform in weight. Similarly for average car weights above 55 to 60 tons the test trains were necessarily uniform in make-up. For trains of average car weights below 20 and above 60 tons the curves of Fig. 10 are accepted, therefore, as valid, and applicable to any train to be met with in practice.

86 In Fig. 10, those portions of the curves corresponding to car weights of from 20 to 60 tons were, on the other hand, derived from trains which presented considerable diversity in make-up as regards weight per car. Some of these trains were composed almost entirely of loaded cars, others contained large proportions of both empty and loaded cars. In presenting the results in the form adopted in Fig. 10 (and Fig. 11), the assumption is that the curves there drawn will be used throughout their entire range of average car weight to determine the total resistance of both homogeneous and mixed trains, and that, when so applied, they will lead to no material error. In view of the facts just stated it is pertinent to inquire whether this assumption is justifiable.

87 Assume two trains of equal tonnage, and of the same average weight per car. Assume further that one is composed of cars uniform in weight, and the other of cars of different individual weights. Now if such trains are to have equal total resistance, it can be shown that the variation in resistance per car of the individual cars must be directly proportional to their weight. This implies that the curve showing the relation between total car resistance and car weight at a given speed must be a straight line, if homogeneous and mixed trains are to have equal total resistances at this speed. From Fig. 10 there have been derived such curves, showing the relation between car resistance and car weight. These curves (not shown in the report) correspond quite closely, but not exactly, with straight lines; and the correspondence is especially close for those portions of the curves which apply to car weights between 20 and 60 tons. From these facts we may conclude that the curves of Fig. 10 are not quite equally applicable to mixed and homogeneous trains, but nearly so, and that if the curves are applied to both kinds of trains, we may expect a slight error in the resulting total train resistance. The amount of such error is indicated by the following examination of a specific case.

88 Assume two trains, *A* and *B*, the first homogeneous, the second mixed, as regards car weight. Train *A* is composed of 60 cars each weighing 45 tons, and its total weight is 2700 tons. Train *B* is composed of 30 cars of 70 tons each and 30 cars of 20 tons each; its total weight is 2700 tons and its average car weight is 45 tons. Train *B* presents about as great a diversity in car weight as may be encountered in current practice. Both trains have equal tonnage and the same average weight per car. Assume that the total resistance of these two trains at a speed of 5 miles per hour is to be determined. By the procedure which it is intended shall usually be followed in using

Fig. 10, the resistance for an average car weight of 45 tons, at 5 miles per hour, is found to be 4.0 lb. per ton; and the total resistance of either train A or train B is $2700 \times 4.0 = 10{,}800$ lb.

89 Train B, however, may be considered as made up of two shorter homogeneous trains of average car weights of 20 and 70 tons respectively, and the resistance of each may be determined from those portions of the curves of Fig. 10 about whose validity no question is raised. From Fig. 10, the resistance at 5 miles per hour for a car weight of 20 tons is found to 6.8 lb. per ton, and for a car weight of 70 tons, 3.1 lb. per ton. By the use, therefore, of these portions of the curves of Fig. 10, the total resistance of train B is found to be $30 \times 20 \times 6.8 + 30 \times 70 \times 3.1 = 10{,}590$ lb., which differs from the resistance previously found by 2 per cent. If similar analysis be made for a speed of 40 miles per hour, the corresponding difference is found to be 4 per cent. If these differences be accepted as a measure of the maximum error likely to result from the indiscriminate application of the curves of Fig. 10 to mixed and homogeneous trains, we may conclude that for purposes of rating locomotives the results of the tests as expressed in Fig. 10 and 11 and Table 3 may be so applied without material error.

90 *The Influence of Speed on Resistance.* Within the last two years the opinion has been expressed in some quarters that train resistance between speeds of 5 and 35 miles per hour is constant. It is proper to point out that there is nothing in the data here presented to support such a conclusion.

91 *The Influence of Wind Velocity on Resistance.* The wind velocities prevailing during the tests were generally less than 20 miles per hour. The data do not permit the influence of such winds to be differentiated from the other elements affecting resistance; but they do warrant the conclusion that this influence is small. In the introduction, train resistance was defined as the resistance in still air, whereas throughout the report the term is applied to the test results from which the influence of wind has not been eliminated. This inconsistency has been deliberately incurred to avoid unwieldy expression, and is partially justified by the facts just stated.

92 *Comparison with other Experiments.* There is no point in comparing the results of these tests with formulæ in which the influence of car weight is given no consideration, nor with those not derived from tests on American cars of recent design. The results obtained on the Chicago, Burlington and Quincy Railroad and on the Pennsyl-

vania Railroad, and recently published by Mr. F. J. Cole are selected for comparison.

93 The results obtained on the Chicago, Burlington and Quincy road ("curve No. 1, for temperatures above 30 deg. fahr. and no wind") apply to a speed of 20 miles per hour. Compared with the curve for 20 miles per hour in Fig. 10, they show resistance values from 35 to 60 per cent lower than the corresponding results of these tests. The Pennsylvania Railroad results are supposed to be equally applicable at all speeds between 5 and 30 miles. When plotted on Fig. 10 of this report they show very close correspondence with the curve there drawn for 10 miles per hour, for car weights from 25 to 70 tons; while for car weights below 25 tons they indicate resistance values as much as 20 per cent in excess of the results obtained during these tests.

[1] Railway Age Gazette, August 27 to October 1, 1909.

APPENDIX

RAILWAY TEST CAR NUMBER 17

The dynamometer car by means of which these tests were made was built in 1900. Under the arrangements then entered into, the car itself was built and has been since maintained by the Illinois Central Railroad; while the University has supplied all apparatus, and has manned and operated the car. Both the car body and the apparatus were remodeled in 1907.[1]

2 The car body was especially designed for its purpose. It is 40 ft. long over the end-sills, and 8 ft. 4 in. wide inside. The central sills and the platforms are of steel, while the remainder of the construction is of wood. The general design of the car is shown in Fig. 1, and an interior view is shown in Fig. 2. The working space occupies about two-thirds of the length of the car, and in it are placed the recording apparatus, the auxiliary instruments, the storage batteries, the work bench, etc.

3 During the tests which are here reported the test-car apparatus made continuous autographic records of drawbar pull, speed, time, mile-post positions, air-brake cylinder pressure, wind velocity with respect to the car, and wind direction with respect to the longitudinal axis of the car. These records were made upon a chart 36 in. wide, drawn across the table of the recording apparatus. During these tests this chart was driven by gearing from the axle of the central truck below the car, so that its travel was proportional to the travel of the car itself. A view of the recording apparatus is shown in Fig. 3.

4 Fig. 4 is reproduced from a tracing of a portion of the chart made during test S–1057 of this series. The only lines there shown which do not appear on the original record, are the profile and the transverse lines which mark the limits of one of the sections selected for calculation. These lines and some of the explanatory lettering have been added to the tracing, in order to make clearer the significance of the various records.

5 The total pull which comes upon the measuring drawbar of the car is transmitted to oil contained in the receiving cylinder, whose design is shown in Fig. 5. This cylinder is hung from the center sills, immediately behind the drawbar yoke. Its inside diameter is 10 in., and its piston is 7 1/2 in. long. Both cylinder and piston are carefully ground to an exact fit and no piston packing is used. The pull is transmitted from the drawbar yoke to the piston, through a roller-borne yoke; and the whole device is practically frictionless. Such leakage of oil as takes place proceeds so slowly as to prove of no inconvenience, even when operating under maximum pull. The cylinder may be refilled with oil

[1] A more detailed description of the present equipment is contained in an article by F. W. Marquis, which appeared in the Railway Age Gazette of February 19, 1909.

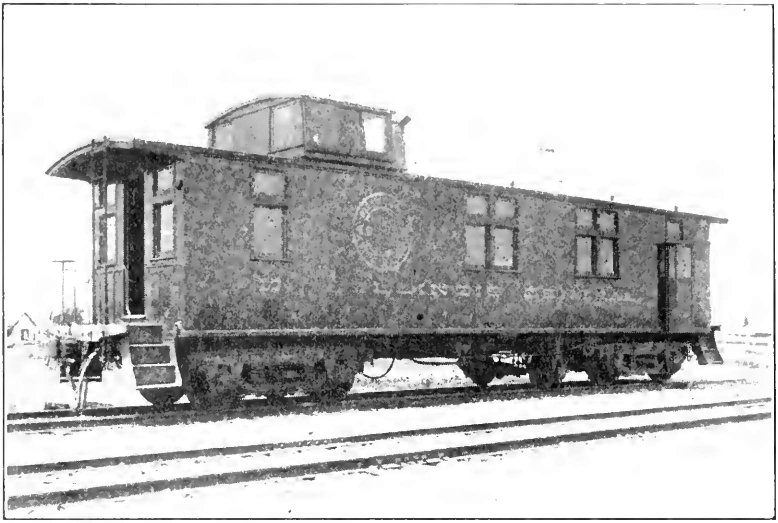

Fig. 1 Railway Test Car No. 17

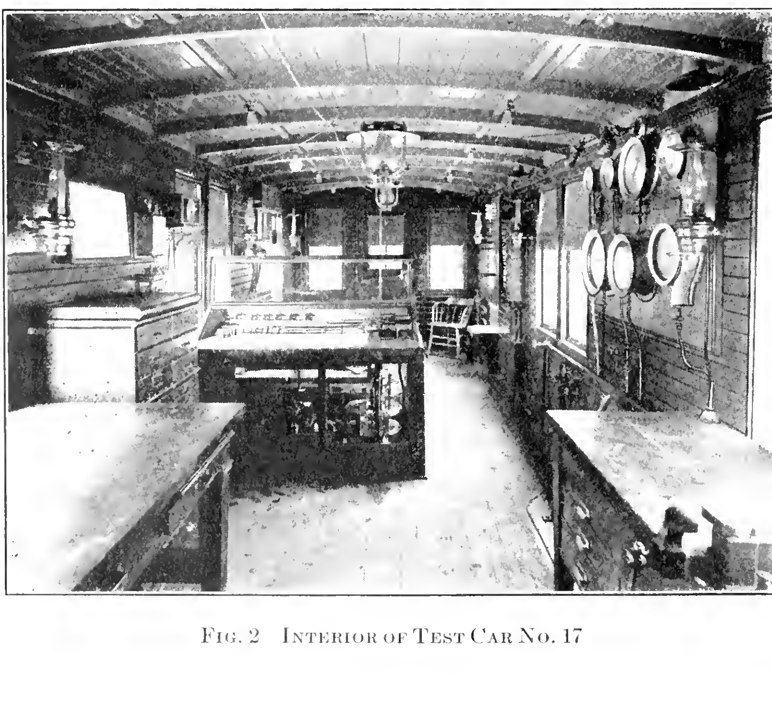

Fig. 2 Interior of Test Car No. 17

by means of a pump within the car while the car is in operation, without impairing the accuracy of the record. The pressure of the oil in this receiving cylinder is transmitted to the cylinder of an indicator located upon the table within the car. This indicator is identical in design with one of the modern types of steam-engine indicators; although it is larger and heavier throughout. During its ten years of service this dynamometer has demonstrated its reliability and accuracy.

6 Two speed records are shown on the chart, and both are used. The one is obtained from a speed recorder which resembles in design a "flyball" engine governor. This instrument is used in measuring speeds above 15 miles per hour. The second record is obtained from a chain-driven Boyer speed recorder, geared to run at about three times its usual speed. This record is used for speeds up to 35 miles per hour. Within their respective ranges, both instruments produce accurate speed curves.

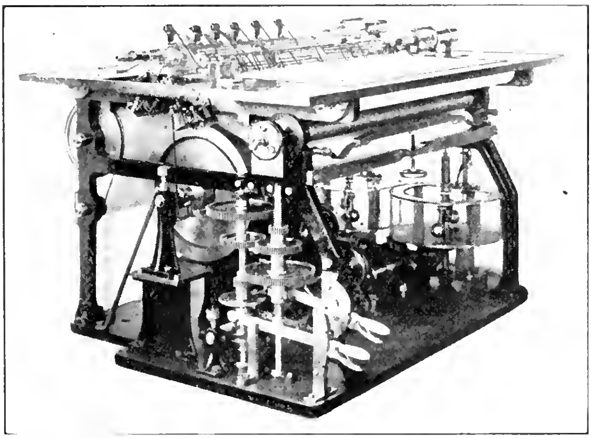

FIG. 3 THE RECORDING APPARATUS

7 The air-brake cylinder of the test car is connected to the cylinder of an ordinary steam engine indicator, which is mounted upon the table and which draws a curve of air-brake cylinder pressure.

8 The velocity of the wind with respect to the car is obtained by means of a Robinson cup-anemometer of the standard United States Weather Bureau type, which is so mounted that the cups revolve 32 in. above the car roof. This instrument controls an electric circuit, which operates an electro-magnet connected to the recording pen. By means of this magnet, offsets are made in the line drawn by the pen. During the time which elapses between two succeeding offsets, the actual movement of the wind amounts to 0.2 of a mile.

9 The direction of the wind with respect to the longitudinal axis of the car, is derived from a wind vane mounted 3 ft. above the car roof. The spindle of the vane extends downward to a point above the recording apparatus, and terminates there in a crank which is parallel to the vane. This crank is con-

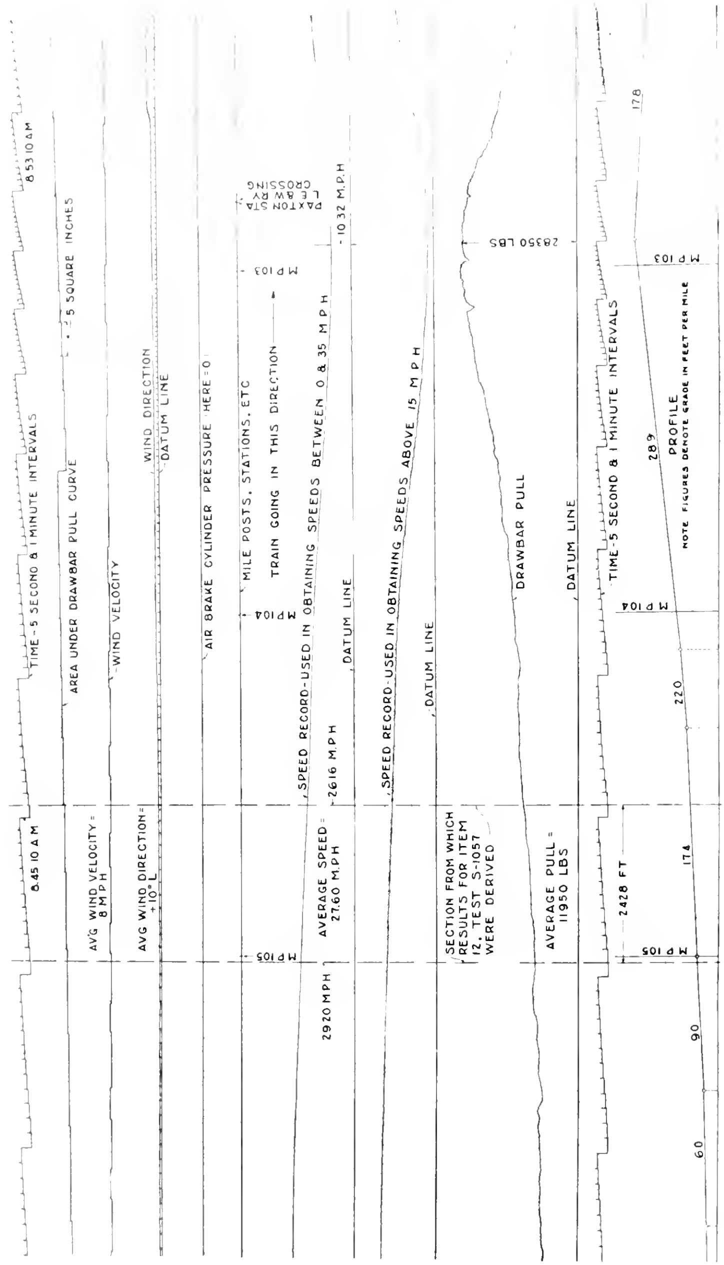

FIG. 4 A PORTION OF THE CHART FROM TEST S-1057

nected to the recording pen through a rod with a yoke end. The ordinate of the curve drawn by this pen is proportional to the sine of the angle made by the vane with the car axis. The offsets in the datum line for this curve which appear in Fig. 4, indicate that the vane, at the moment, was pointed toward the front end of the car.

10 Fig. 4 shows a record of "area under the curve of pull" which is made by means of a recording planimeter mounted on the table. This record is inaccurate and was not used in these calculations.

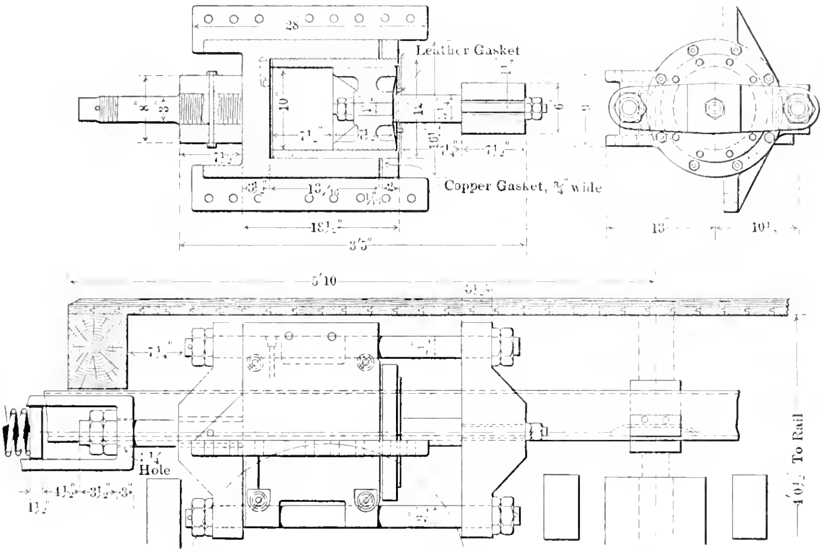

Fig. 5 Receiving Cylinder of the Dynamometer

EXACT COÖRDINATES FOR THE CURVES OF FIGS. 10 AND 11.

11 The original drawings from which Figs. 10 and 11 of the paper have been reproduced, were drawn to a scale about four times as great as that of the cuts. From these original drawings, the values of the coördinates of the various curves of both figures have been determined as accurately as possible; and these values are presented in Tables 1 and 2 herewith.

12 The curves of Fig. 10 (and of Figs. 3 to 9) of the paper may be accurately reproduced by the use of Table 4; and the curves of Fig. 11 may be reproduced from the values given in Table 2 herewith. The tables are presented merely to permit the accurate reproduction, to any scale, of the curves of the report; and are not intended for use in determining values of resistance. For the latter purpose Table 3 of the paper is more convenient and sufficiently accurate.

TABLE 1a RESISTANCE AT DIFFERENT SPEEDS AND FOR TRAINS OF VARIOUS AVERAGE CAR WEIGHTS

THIS TABLE PRESENTS THE COÖRDINATES OF THE ORIGINAL CURVES FROM WHICH FIGS. 3 TO 9 AND FIG. 10 WERE REPRODUCED

Average Weight per Car Tons	Train Resistance—Pounds per Ton Column headings indicate the various speeds							Average Weight per Car Tons
	5 m.p.h.	10 m.p.h.	15 m.p.h.	20 m.p.h.	25 m.p.h.	30 m.p.h.	35 m.p.h.	
15	7.62	8.20	8.81	9.56	10.37	11.24	12.25	15
16	7.44	8.00	8.61	9.34	10.13	10.98	11.95	16
18	7.10	7.63	8.22	8.92	9.68	10.47	11.39	18
20	6.77	7.30	7.85	8.53	9.26	10.00	10.89	20
22	6.45	6.97	7.49	8.16	8.84	9.56	10.41	22
24	6.16	6.64	7.14	7.79	8.46	9.16	9.94	24
25	6.02	6.50	6.98	7.62	8.28	8.95	9.72	25
26	5.88	6.35	6.81	7.44	8.10	8.77	9.52	26
28	5.61	6.07	6.51	7.11	7.76	8.40	9.12	28
30	5.38	5.80	6.23	6.80	7.43	8.05	8.75	30
32	5.13	5.54	5.98	6.51	7.12	7.72	8.40	32
34	4.92	5.31	5.72	6.24	6.82	7.40	8.06	34
35	4.82	5.20	5.61	6.11	6.68	7.26	7.91	35
36	4.72	5.10	5.50	5.99	6.55	7.11	7.77	36
38	4.55	4.90	5.28	5.74	6.29	6.83	7.48	38
40	4.38	4.70	5.06	5.50	6.03	6.57	7.20	40
42	4.22	4.52	4.88	5.29	5.80	6.32	6.95	42
44	4.08	4.38	4.70	5.09	5.59	6.10	6.71	44
45	4.01	4.30	4.61	4.99	5.49	6.00	6.60	45
46	3.95	4.21	4.52	4.90	5.38	5.90	6.49	46
48	3.82	4.08	4.38	4.71	5.20	5.71	6.28	48
50	3.72	3.96	4.24	4.56	5.03	5.52	6.10	50
52	3.61	3.85	4.11	4.42	4.88	5.36	5.91	52
54	3.52	3.75	3.99	4.30	4.74	5.20	5.74	54
55	3.48	3.71	3.94	4.25	4.68	5.12	5.67	55
56	3.43	3.67	3.90	4.20	4.62	5.05	5.60	56
58	3.37	3.58	3.81	4.10	4.50	4.93	5.47	58
60	3.30	3.50	3.73	4.02	4.42	4.83	5.36	60
62	3.23	3.44	3.67	3.97	4.34	4.74	5.27	62
64	3.18	3.39	3.60	3.90	4.29	4.68	5.18	64
65	3.15	3.36	3.58	3.88	4.25	4.64	5.14	65
66	3.12	3.32	3.55	3.85	4.22	4.61	5.11	66
68	3.09	3.30	3.50	3.80	4.18	4.57	5.06	68
70	3.05	3.26	3.47	3.76	4.13	4.52	5.01	70
72	3.02	3.22	3.44	3.73	4.10	4.49	4.98	72
74	3.01	3.19	3.42	3.71	4.08	4.48	4.93	74
75	3.00	3.18	3.41	3.70	4.07	4.47	4.91	75

TABLE 26 RESISTANCE AT DIFFERENT SPEEDS AND FOR TRAINS OF VARIOUS AVERAGE CAR WEIGHTS

This Table Presents the Coördinates of the Original Curves from which Fig. 11 was Reproduced

Speed Miles per Hour	Train Resistance—Pounds per Ton. Column headings indicate the average car weights: 15 tons	20 tons	25 tons	30 tons	35 tons	40 tons	45 tons	50 tons	55 tons	60 tons	65 tons	70 tons	75 tons	Speed Miles per Hour
5	7.62	6.77	6.02	5.38	4.82	4.39	4.01	3.72	3.49	3.30	3.16	3.05	3.00	5
6	7.73	6.86	6.12	5.46	4.90	4.43	4.07	3.77	3.52	3.33	3.19	3.08	3.03	6
7	7.83	6.97	6.21	5.53	4.98	4.50	4.12	3.81	3.56	3.37	3.23	3.12	3.07	7
8	7.96	7.06	6.31	5.62	5.04	4.57	4.18	3.86	3.60	3.40	3.26	3.16	3.10	8
9	8.07	7.18	6.40	5.71	5.11	4.62	4.22	3.90	3.64	3.44	3.30	3.20	3.13	9
10	8.19	7.29	6.50	5.80	5.20	4.69	4.28	3.96	3.69	3.49	3.34	3.24	3.18	10
11	8.30	7.40	6.60	5.90	5.29	4.76	4.33	4.00	3.73	3.52	3.38	3.29	3.21	11
12	8.42	7.51	6.71	5.98	5.37	4.83	4.40	4.04	3.78	3.58	3.42	3.33	3.26	12
13	8.56	7.63	6.81	6.08	5.46	4.90	4.47	4.11	3.83	3.62	3.47	3.38	3.31	13
14	8.70	7.76	6.92	6.18	5.53	4.98	4.53	4.18	3.89	3.68	3.52	3.43	3.36	14
15	8.82	7.88	7.01	6.28	5.64	5.06	4.60	4.24	3.94	3.73	3.57	3.48	3.41	15
16	8.98	8.00	7.12	6.39	5.73	5.13	4.68	4.31	4.00	3.80	3.62	3.53	3.47	16
17	9.10	8.13	7.24	6.49	5.82	5.23	4.75	4.38	4.05	3.86	3.68	3.60	3.52	17
18	9.25	8.27	7.37	6.60	5.92	5.32	4.83	4.45	4.12	3.92	3.74	3.66	3.58	18
19	9.40	8.40	7.49	6.71	6.01	5.41	4.91	4.52	4.19	3.98	3.81	3.72	3.64	19
20	9.56	8.53	7.60	6.82	6.11	5.50	5.00	4.60	4.27	4.04	3.88	3.79	3.71	20
21	9.71	8.69	7.72	6.93	6.22	5.60	5.08	4.69	4.32	4.11	3.94	3.85	3.78	21
22	9.88	8.82	7.86	7.03	6.33	5.70	5.17	4.78	4.41	4.18	4.00	3.92	3.84	22
23	10.02	8.97	7.99	7.14	6.44	5.80	5.27	4.86	4.49	4.25	4.07	3.99	3.92	23
24	10.20	9.11	8.11	7.27	6.55	5.90	5.37	4.94	4.58	4.33	4.15	4.06	3.98	24
25	10.37	9.26	8.25	7.40	6.67	6.01	5.46	5.03	4.66	4.41	4.23	4.13	4.04	25
26	10.52	9.42	8.38	7.52	6.79	6.11	5.57	5.12	4.75	4.50	4.31	4.21	4.12	26
27	10.71	9.57	8.51	7.65	6.91	6.21	5.67	5.22	4.83	4.58	4.40	4.29	4.20	27
28	10.89	9.72	8.67	7.78	7.01	6.33	5.78	5.32	4.92	4.67	4.48	4.38	4.29	28
29	11.06	9.89	8.81	7.91	7.12	6.45	5.88	5.43	5.01	4.76	4.57	4.46	4.36	29
30	11.25	10.03	8.96	8.04	7.26	6.58	5.99	5.53	5.11	4.86	4.66	4.53	4.45	30
31	11.43	10.20	9.10	8.18	7.39	6.71	6.10	5.64	5.21	4.95	4.75	4.63	4.53	31
32	11.63	10.37	9.26	8.31	7.51	6.83	6.21	5.76	5.32	5.04	4.85	4.73	4.62	32
33	11.84	10.53	9.41	8.46	7.63	6.96	6.33	5.87	5.43	5.15	4.95	4.83	4.72	33
34	12.04	10.71	9.57	8.60	7.78	7.08	6.47	5.99	5.54	5.26	5.05	4.92	4.82	34
35	12.25	10.89	9.72	8.75	7.91	7.20	6.60	6.10	5.67	5.36	5.16	5.01	4.92	35
36	12.47	11.07	9.89	8.90	8.04	7.35	6.73	6.23	5.78	5.48	5.27	5.12	5.01	36
37	12.69	11.23	10.04	9.04	8.19	7.49	6.87	6.36	5.90	5.59	5.38	5.22	5.12	37
38	12.91	11.42	10.21	9.20	8.33	7.64	7.00	6.49	6.02	5.71	5.48	5.33	5.22	38
39	13.12	11.61	10.39	9.36	8.48	7.79	7.13	6.63	6.15	5.83	5.60	5.44	5.33	39
40	13.35	11.80	10.55	9.51	8.62	7.93	7.29	6.78	6.28	5.95	5.72	5.55	5.45	40

THE STRENGTH OF PUNCH AND RIVETER FRAMES MADE OF CAST IRON

BY PROF. A. LEWIS JENKINS, CINCINNATI, O.

Member of the Society

The actual stress relations existing in a simple cast-iron beam when subjected to a load have been the object of many investigations conducted by engineers during the past hundred years. These investigations consisted of numerous experiments and mathematical deductions for the determination of the elastic laws and physical constants involved in the analysis of stresses in straight cast-iron beams, but did not include the necessary deductions for the case of curved beams similar to punch and riveter frames.

2 The object of this article is to determine experimentally the relation between the ultimate strength of curved cast-iron specimens similar to punch and shear frames and the ultimate strength of the attached test bars and to compare the experimental results with those determined by the various methods of analysis used in designing castings of similar shape. In making this investigation many publications relating to the subject have been studied and the most important results many of which are only of historical interest are stated and discussed in the appendix.

FACTOR OF SAFETY

3 It has been contended that the ultimate strength of cast-iron machine parts is of no practical value since the working stress seldom exceeds 5000 lb. per square inch, and as Hook's law is sensibly true within this limit the ordinary formulas for beams should apply with a fair degree of accuracy. It is frequently desirable, however, to know the ultimate strength of such elements as punch frames in order to design the safety link which is supposed to break and save the frame in case of an accident or overload.

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4 The ordinary formulas assume that the stress in a beam is directly proportional to the load and factors of safety based on the ultimate tensile strength of the material are the same as if based on the ultimate strength of the beam. This is not true, however, for cast-iron because the stress is not directly proportional to the load. A beam 1 in. square and 12 in. between supports made of cast iron having an ultimate tensile strength of 20,000 lb. per square inch would support a load of 222 lb. midway between the supports with a factor of safety of 5 based on the ultimate tensile strength. Such a beam would probably fail, however, under a load in the middle of about 2000 lb. giving a factor of safety of 9 based on the breaking load of the beam. Hence, by using the ordinary beam formulas in designing straight cast-iron machine elements that are to be subjected to bending strains the actual working stress may be close to that desired, but the actual factor of safety based on the strength of the casting will be much greater than the factor of safety based on the tensile strength of the material.

Methods Employed in Making Tests

5 For many years engineers have recognized the value of experimental data on the strength of cast-iron beams and a considerable volume of literature on this subject is now available. There are, however, no published data on the strength of curved beams similar in shape to punch frames. The results of some experiments on the strength of crane hooks published in the October 7, 1909, issue of the American Machinist, seem to show that the Pearson-Andrews formula is true within the elastic limit for steel specimens of small throat depth. It will be noticed, however, that the value used for Poisson's ratio does not compare favorably with the values of this constant usually given for steel.

6 In view of the fact that there seems to be no rational method for determining the strength of curved cast-iron beams the writer believes that some experimental data on this subject may be of practical value and also serve as an incentive for further investigation by others.

7 Three forms of test specimens as shown in Figs. 1, 2 and 3 were used for these tests. These specimens were carefully designed with a view to having them of equal strength throughout, the calculations being based on the ordinary formulas for beams. To prevent any torsional moment due to eccentric loading the specimens were provided with two small hemispherical projections for receiving the load. A round and a rectangular test bar were cast with each specimen as

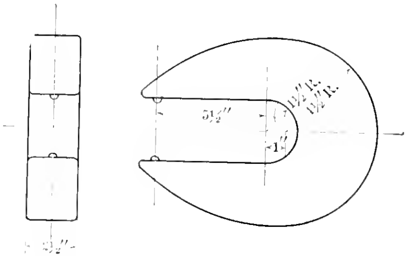

Fig. 1 Dimensions of Specimens 1, 2 and 3, Plate I

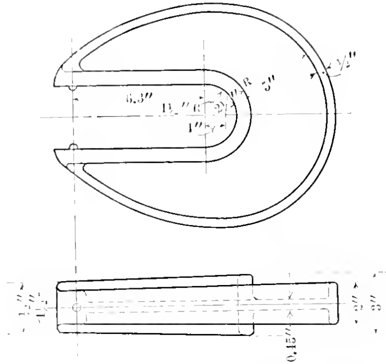

Fig. 2 Dimensions of Specimens 4, 5, 7 and 12, Plates I and II

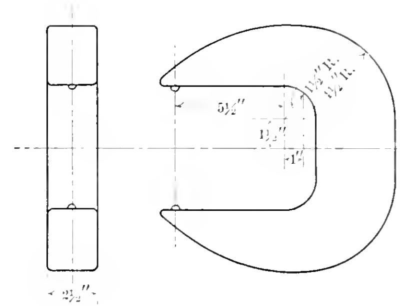

Fig. 3 Dimensions of Specimens 16 and 17, Plate III

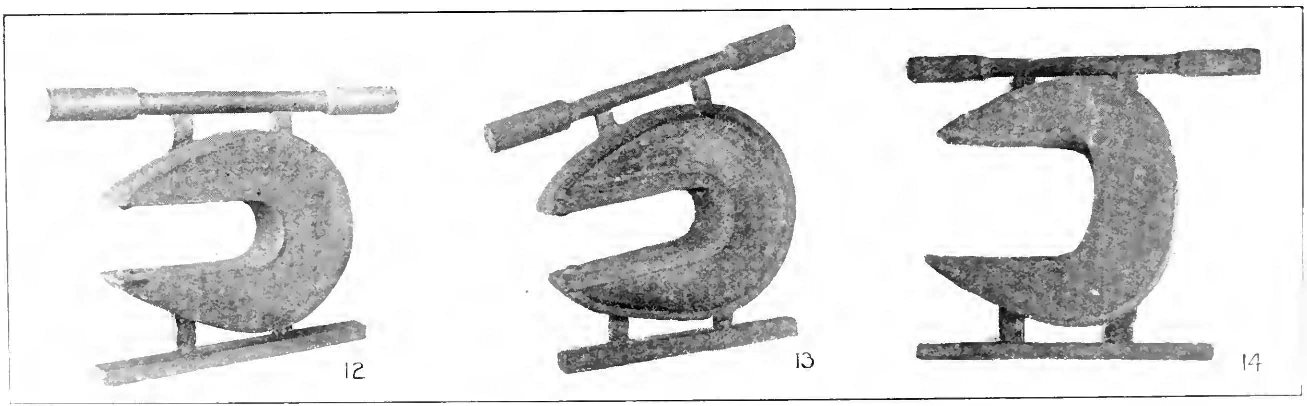

Fig. 4 Round and Rectangular Test Bars Cast with Each Specimen

shown in Fig. 4. The castings were made by the Buckeye Foundry Company of Cincinnati and poured from a heat run to cast lathe beds.

8 The 100,000 lb. Riéhle testing machine shown in Fig. 5 was used for making the tests. Fig. 6 shows the method employed for applying the load. Two stirrups forged from 1 in. by 3 in. steel and then tem-

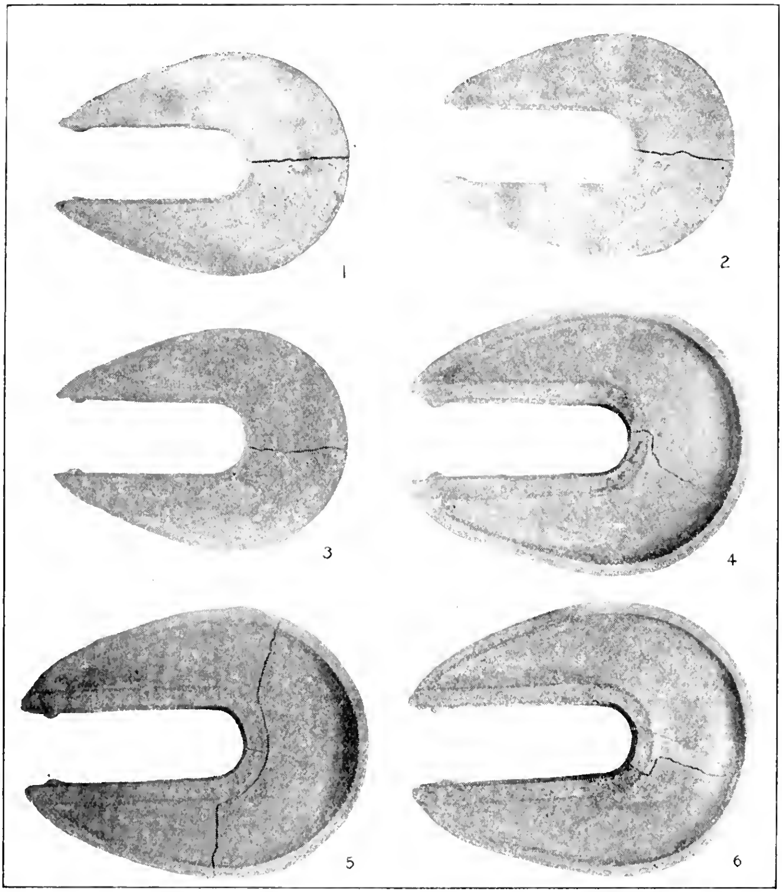

Plate I Curved Cast-Iron Specimens Broken by Tests

pered were held in the grips and received the castings. The tangs of the autographic recorder were placed between the casting and the stirrups, thereby eliminating the deflection of the stirrups and the bearing projections on the castings.

SIZE OF SPECIMENS

9 Plates I, II, and III were made from photographs of the broken specimens. The dimensions of specimens No. 1, 2 and 3 are shown in Fig. 1, and Fig. 2 shows the dimensions of specimens No. 4, 5, 7 and 12. The flanges on No. 12 were partially removed, but this did not

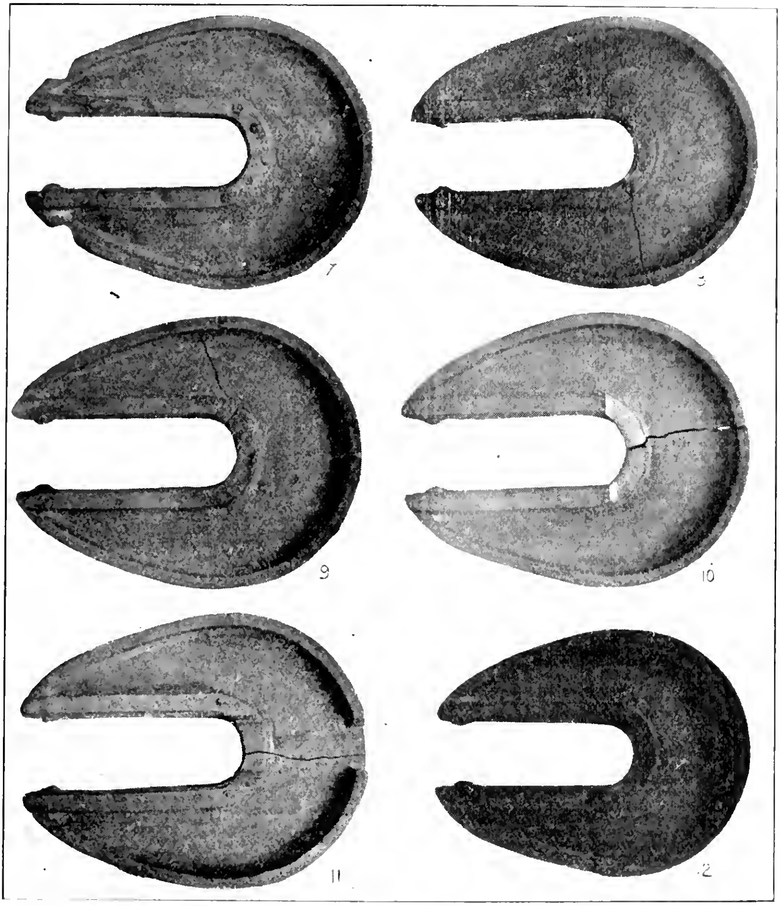

Plate II Curved Cast-Iron Specimens Broken by Tests

affect its strength. Specimens No. 9, 10, 11 and 13 were cast from the same pattern as No. 4 and the flanges altered as shown. No. 6 was cast from the same pattern as No. 4 after the thickness of the web had been increased to 0.93 in. No. 14 differs from No. 6 in that the fillet behind the flange is larger. No. 15 is the same as No. 14 with the out-

side flange removed. Fig. 3 shows the dimensions of No. 16 and 17. No. 18 is the same as No. 16 with depth of spine reduced to 3.4 in.

RESULTS OF TESTS

10 Table 1 gives the results of the tests. The unit tensile strength of the test bars varied from 18,600 to 24,400 lb., and the flexural

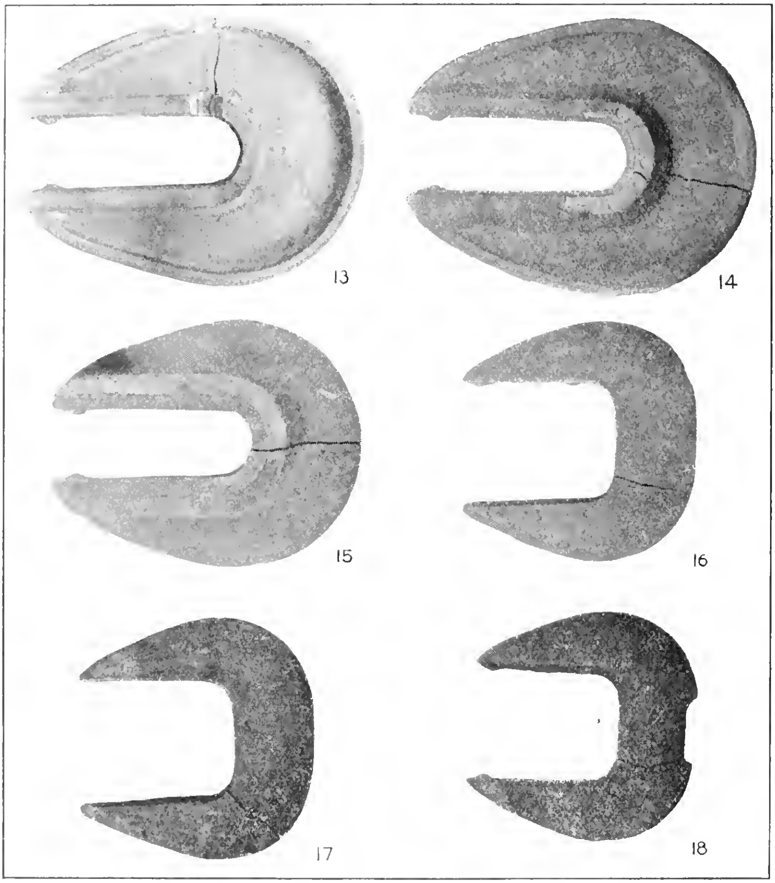

PLATE III CURVED CAST-IRON SPECIMENS BROKEN BY TESTS

strength varied from 36,400 to 46,400 lb. The variations in the values of K seem to indicate that no definite relation exists between the tensile and flexural strength of small test bars.

11 The determination of the correct value for the radius of curvature of the gravity axis is extremely important and considerable care

was exercised in attempting to get accurate measurements of these values by plotting the curve of the gravity axis and finding its radius of curvature at the section considered in each case. It is possible for the personal equation to cause sufficient variations in these values to affect appreciably the final results. The chances for errors in plotting the transformed curves and measuring their areas is also worthy of the designer's consideration in choosing a formula.

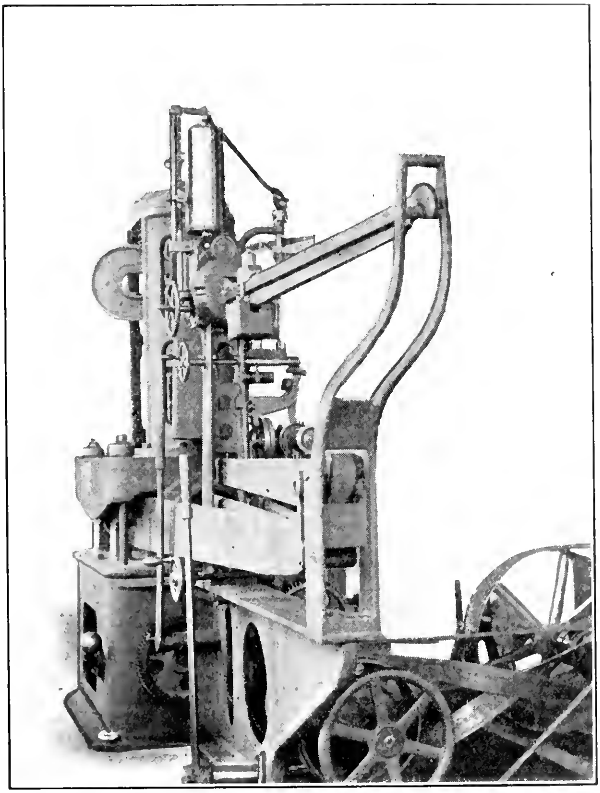

FIG. 5 100,000-LB. RIEHLE TESTING MACHINE

12 The average dimensions of castings No. 1, 2, and 3, Plate I, cast from the same pattern, are given in Fig. 1. Each casting was carefully measured and the values used in the respective calculations. The average tensile strength of the three test bars is 18,907 lb. per square inch. The maximum stress in the castings at failure as given by the beam formula is 14.2 per cent less than the tensile strength of the

test bar, whereas the stress according to the Résal and Pearson-Andrews formulas is 43.4 per cent and 75.4 per cent in excess of the strength of the test bar.

13 From Keep's experiments it is known that the unit strength of cast-iron bars of the same composition decreases as the area increases; hence, it is reasonable to suppose that the unit stress given by the beam formula is very close to the actual ultimate strength of the material.

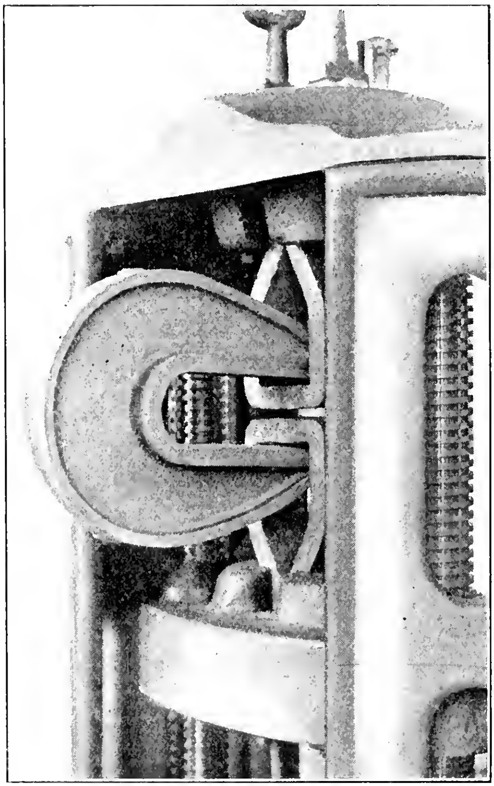

Fig. 6 Method Employed in Applying Load

The absurd results given by the Résal and Pearson-Andrews formulas in this case show that they are not applicable to this condition.

14 Castings No. 4, 5, 7, 9 and 12, Plates I and II, were cast from the same pattern and the average dimensions are given in Fig. 2. None of the above-mentioned formulas apply to these castings owing to the peculiar manner in which they failed. The results, however,

have an extremely important bearing on the design of punch frames. These specimens were supposed to fail under a load of about 15,000 lb When the load on No. 4 reached 9300 lb. a fracture occurred behind the inner flange, as shown in the photographs of castings No. 7 and 12. Continued application of the load produced the fractures shown on No. 4, 5 and 9. The stress producing failure was evidently a normal stress as there is no shear on this section.

TABLE 1 RESULTS OF TESTS

	Tension Specimens			Transverse Specimens Length 12 in.				Curved Specimens			
									Unit stress at ab		
Test No.	Breaking Load	Area Sq. In.	Stress Pounds Per Sq. In.	Breaking Load	Area (Breadth × Depth)	$S = \frac{MC}{I}$	$K = S_t \frac{bd^2}{M}$	Breaking Load	Beam Formula	Résal's Formula	Pearson-Andrews Formula
1	15000	0.785	19100	2380	.75 × 1.25	36560	3.14	11200	16240	27025	33013
2	14630	0.785	18620	2880	.75 × 1.25	44200	2.52	11125	16120	26844	32796
3	13460	0.709	19000	1680	1.25 × .75	46080	2.65	11390	16540	27484	33577
4	17000	0.785	21630	2280	1 × 1.05	37200	3.48	9300	11330	19583	38223
5	17000	0.785	21630	2000	1 × .95	40000	3.25	8500	10500	17909	34935
6	15500	0.833	18600	2160	1 × 1	39000	2.86	12600	22520	25870	29460
7	16300	0.866	18750	2380	1 × 1	43000	2.62	12000	9790	12584	27048
8	15070	0.724	21700	2310	1 × .95	46250	2.82	15300	12600	18420	
9	18000	0.785	22920	2200	1 × 1	39600	3.97	8300	10130	19164	36530
10	16000	0.785	20370	2300	.95 × 1	43700	2.70	8400	10520	——	——
11	17800	0.754	23600	2060	1.02 × 1	36400	3.94	5200	18420	21040	
12	18000	0.785	23000	2070	1 × .98	38000	3.56	8400	10235	17500	34524
13	18000	0.754	24400	2440	1 × .98	45000	3.20	5800	——	——	——
14	16300	0.739	21800	2300	1.02 × 1	40600	3.22	12700	23920	26435	28700
15	16100	0.754	21400	2240	1 × 1	40400	3.18	12500	23400	26025	28250
16	16730	0.785	21270	2460	.75 × 1.25	37800	3.41	11255	16320	27160	33300
17	17340	0.785	22080	2741	.75 × 1.25	42200	3.17	11980	17270	28987	35400
18	17900	0.785	22800	2680	.75 × 1.25	41300	3.35	10600	21476		

15 The conditions of stress that would produce such a failure may be given as follows:

a The inner flange being heavier than the web would tend to produce separation behind the flange due to unequal contraction when cooling. This initial stress due to cooling, plus the stress due to lateral contraction caused by the tensile stress due to bending, is a stress normal to the plane of

fracture. This method gives about 1500 lb. for the stress due to the load and about 18,000 lb. for the initial stress due to cooling, which is considered absurd. Hence this method does not offer a satisfactory explanation.

b In Fig. 7, given in the appendix, the load W produces a bending moment at the section AD equal to WN. This moment is resisted by the moment $\frac{SI}{c}$ where S is the sterss at A, I the moment of inertia of the section between A and D, and c the distance between the center of gravity of this section and the point A. The fracture of casting No. 5 suggested this method as a possible cause of failure. At a load of 8500 lb. a fracture occurred behind the inner flange and the load dropped almost to zero. Upon further application of the load the crack gradually approached the outer flange, then the inner flange fractured and finally the outer flange separated. According to this method of analysis the average unit stress at A in the five castings was about 22,700 lb. when the fracture occurred, which is excessive for tensile strength. This does not consider a possible shifting of the neutral axis, however, which would tend to decrease the value of the result. There are also reasons for using a larger value for N. By changing the values of N and c, it is possible to change the value for the stress, hence this method could not be relied upon without making many tests on different-sized specimens with different thicknesses of flange.

c Considering the flanges as separate members having pin connections at points A, E, F and G in Fig. 8, the load W would tend to increase the distance between the points A and G. If A and G be connected by means of a link, the stress in it may be found as follows: Draw the lines EG, FG, EA, and FA and let them represent links with pin connections. Then produce GA until it cuts the line of application of the load at K. The triangle AKE may be taken as the force diagram where $KE = \frac{W}{2}$ and KA is equal to half the stress in the link AG. In the specimen, this stress is taken by the web, the area of which is the outside

diameter, pp, of the inner flange multiplied by the thickness of the web. According to this method the unit stress is about 18,000 lb., which seems to express the stress relation very satisfactorily for this particular case, but it is not probable that such results would be derived from castings having a thicker flange.

16 Casting No. 7, Plate II, was first subjected to a compressive load acting on the horizontal side of the notches cut in the outer flange. This caused failure near the line of application of the load, as shown in the photograph. It was then subjected to a tensile load acting at a distance of $5\frac{3}{16}$ in. from the inside of the spine.

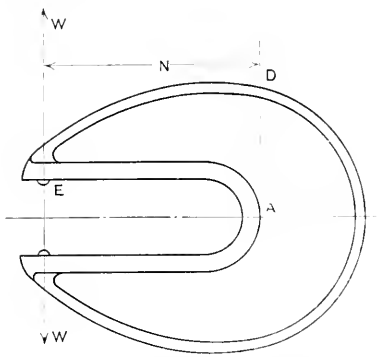

Fig. 7 Diagram Showing Condition with Bending Moment at Section AD

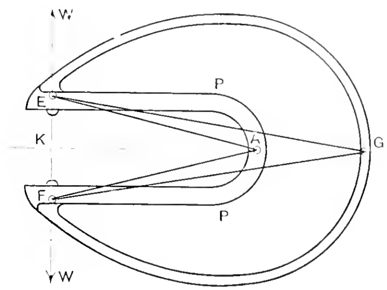

Fig. 8 Diagram Showing Condition Producing Tensile Stress in Section AG

17 Casting No. 9 had $\frac{3}{16}$ in. of the outer flange removed on both sides. This, however, did not seem to affect its strength.

18 Casting No. 12 had the outer flange removed on both sides and the inner flange reduced to 1 in. wide at a distance of $6\frac{1}{2}$ in. from the load line; but this did not seem to affect its strength. The unit stress at the milled section according to the formula $S = \frac{Mc}{I}$ was 34,805 lb.

19 Casting No. 10 had the inner flange reduced to $2\frac{1}{2}$ in. wide and failed horizontally as shown. Failure in this manner was probably due to a flaw in the inner flange that extended into the web.

20 Casting No. 11 had about 2 in. of the outer flange removed on both sides and the width of the inner flange reduced to 2 in.

21 Casting No. 13, Plate III, had both flanges removed at a distance of 6.8 in. from the line of application of the load. The stress at

this point according to the formula $S = \frac{Mc}{I}$ is 31,160 lb. per square inch.

22 Casting No. 6 is the same as shown in Fig. 2 with the exception of having the thickness of the web increased to 0.93 in. The fracture occurred at an angle of about 30 deg. with the horizontal. There seemed to be a tendency for the fracture to follow the inner flange.

23 Casting No. 8 was subjected to a compressive load and failed at a section 7 in. from the line of application of the load, the stress being 35,370 lb. according to the formula for beams.

24 Casting No. 14 had the thickness of the web increased to 0.93 in. and provided with large triangular fillets behind the inner flange. By comparing the results of this test with those from No. 6, it seems that enlarging the fillet does not appreciably affect the strength of the casting.

25 Casting No. 15 is the same as No. 14 with the outer flange removed. The results seem to show that the outer flange on No. 14 adds but little to its strength.

26 Casting No. 16 failed in a curved portion. The angle between the plane of fracture and line of application of the load is about 79 deg. The stress in this section by Formula 7 (see Appendix) was 16,300.

27 Casting No. 17 failed in a curved portion, the angle being about 48 deg. The stress in the fractured section by Formula 7 (see Appendix) was 17,300.

28 Casting No. 18 is the same as No. 16 and No. 17 with the depth of spline reduced to 3.4 in. The stress at fracture was 21.476.

THE AUTOGRAPHIC RECORDER

29 The autographic recorder gave an apparently straight line for the deflection-load diagram for each specimen, but the scale of the curve is so small that a slight curvature due to the elastic law would not be perceptible. It is interesting to know, however, that the curve is so nearly a straight line and does not show any change in the elastic law which might be taken as the elastic limit of the specimen.

30 The load-deflection curve shows the total deflection produced by any given load on the specimen, and a sudden change in its direction would indicate that the stress in some section had reached the yield point. Any method of analysis involving the use of these curves is only applicable to the section which yields first. In the case of steel specimens it is difficult to determine this section, and in the analysis of stresses in cast-iron specimens the diagram finds no application.

CONCLUSIONS

31 Although these experiments are not sufficiently exhaustive to render any rigid conclusions, they seem to indicate that the following statements are approximately true:

a There is no rational method for predicting the strength of curved cast-iron beams suitable for punch and shear frames.

b Of the three formulas suggested for the design of punch frames, the well known beam formula,

$$S = \frac{Mc}{I} + \frac{W}{R}$$

is the most accurate statement of the law of stress relations existing in such specimens.

c The stress behind the inner flange at the curved portion is an important consideration that should be recognized by the designer.

d There seems to be no definite relation existing between the strength of a curved cast-iron beam and the transverse strength of a test bar cast with it.

e The Résal and Pearson-Andrews formulas are unwieldy and awkward in their application and offer many chances for error.

Acknowledgment is due to Prof. S. E. Slocum for criticisms during the preparation of this article and to Prof. John T. Faig whose assistance made possible the securing of the materials necessary for conducting the tests.

APPENDIX

ELASTIC LAW

Within the elastic limit, homogeneous materials such as steel and wrought iron conform with Hook's law, which states that the stress varies directly as the strain; hence the stress-strain diagram is a straight line. In common practice the elastic limit for cast iron is assumed to be about 6000 lb. per square inch and Hook's law is supposed to be practically true for stresses not exceeding this value but, as a matter of fact, cast iron has no definitely defined elastic limit like steel, and no portion of the stress-strain diagram is a straight line. The elastic law in this case may be expressed by the exponential equation

$$\Delta = K\,S^{m}$$

Where $\triangle$ denotes the unit deformation, S the unit stress, and K and m are constants. From the experiments of Bach these constants have been determined for cast iron, and the elastic laws found to be as follows:

$$\text{For tension,}\ \Delta = 0.00001111\,S^{1.0663}$$

$$\text{For compression,}\ \Delta = 0.00001444\,S^{1.0395}$$

2 These experimental curves may be replaced by parabolas without introducing any serious error. From experiments by Hodgkinson, the equations of the parabolas which fit these stress-strain diagrams most closely were found to take the form

$$S = 1{,}400{,}000\,\Delta\,(1 - 209\,\Delta)\ \text{for tension}$$

$$S = 1{,}300{,}000\,\Delta\,(1 - 40\,\Delta)\ \text{for compression}$$

3 By assuming that the equation of the elastic law is a parabola, the stress in a beam at a distance y from the neutral axis was expressed by St. Venant in the equations,

$$S = T\left[1 - \left(1 - \frac{y}{c}\right)^{m}\right]\ \text{for tension}$$

$$S' = C\left[1 - \left(1 - \frac{y}{c'}\right)^{m}\right]\ \text{for compression}$$

where T and C denote the ultimate tensile and compressive strengths, c and c' the distance from the neutral axis to the extreme fiber in tension and compression respectively, and m a constant so chosen as to make the parabola fit the stress-strain diagram for the given material. For the value $m = 1$, these equations reduce to the form

$$S = T\,\frac{y}{c}$$

which is Hook's law.

POSITION OF THE NEUTRAL AXIS AND THE MOMENT OF RESISTANCE

4 The equation

$$M = \frac{SI}{c}$$

is commonly known as the fundamental formula for beams. This formula is due to Navier and is based on the following assumptions: first, the strain is directly proportional to the distance from the neutral axis; second, the neutral axis coincides with the gravity axis; third, the stress is directly proportional to the strain on both the tension and compression sides. Some authorities favor the validity of the first assumption, but they all in general agree that the second and third are not true for cast iron.

5 The fact that the flexural strength given by the above formula does not coincide with the tensile strength has reflected discredit upon it. The flexural strength is from 1.5 to 2 times the tensile strength for ordinary test bars. The cause of this discrepancy is frequently explained by saying that the formula is based on Hook's law, and is not expected to hold true above the elastic limit, hence it does not give the actual tensile strength at rupture. This statement, however, is not necessarily true, because the formula will represent the stress relations in a rectangular beam under all conditions of load provided the coefficients of elasticity for tension and compression are equal.

6 The discrepancy is due to the shifting of the neutral axis which is caused by the difference in the elastic laws for tension and compression. A method for determining the position of the neutral axis is given by St. Venant in his notes on Navier's Resistance of Solid Bodies. Assuming that the strain varies directly as the distance from the neutral axis, the stress will vary as in the ordinary stress-strain diagram. Now if the beam fails in tension, the stress at rupture on the extreme fiber on the tension side is equal to the ultimate strength of the material.

7 Let $BE = S_t$ represent the ultimate tensile strength of the material, and let OE and ODF represent the stress-strain diagrams for tension and compression respectively as shown in Fig. 1. Then OB is the distance of the neutral axis from the tension side of the beam drawn to the same scale as yet undetermined, and the area OEB represents the total tensile stress in the beam at this section. But since the total tensile and compressive stresses must be equal, the compressive side of the beam is found by drawing a line AD such that the area OAD is equal to the area OEB. OA will then represent the distance of the compressive side of the beam from the neutral axis to the same scale as that to which OB is drawn. The scale may be easily determined by comparing AB with the actual depth of the beam.

8 The stress-strain diagram for the compression side is more nearly a straight line than that of the tension side. By assuming that the compression side obeys Hook's law, the formula for the moment of resistance is thereby simplified and becomes for a rectangular section of breadth b and depth d,

$$M = S\frac{bd^2}{6}\left[\frac{m\left(\frac{3(m+3)}{m+2}+1\right)\sqrt{\frac{2}{m+1}}}{m+3+2\sqrt{2(m+1)}}\right]$$

The value of m in this equation is to be so chosen as to make the expression for the elastic law conform as closely as possible with the actual stress-strain diagram. This equation for any given material reduces to the form

$$S = \frac{MK}{bd^2}$$

9 Hodgkinson's[1] experiments led him to conclude that the neutral axis did not coincide with the gravity axis just at the point of failure of a cast-iron beam, that it moved toward the compression side, dividing the depth into a ratio of 1:5 or 1:6, which is the ratio of the ultimate strengths of the material in tension and compression.

10 W. H. Barlow[2] experimented with beams 7 ft. long, 6 in. deep and 2 in. wide, and found that loads less than three-fourths of the breaking load did not change the neutral axis materially, but just before rupture the shifting became greatly increased. These experiments accounted for only a small percentage of the discrepancy assumed by Hodgkinson.

11 Another explanation is that the outer fibers are subjected to an initial compressive stress due to their being cooled before the inner portion of the beam, and this initial stress must be overcome before the tensile stress begins.

12 Lewiston[3] proposed the theory that the compression side of a cast-iron beam is stressed to its ultimate strength at the point of failure. That is to say, a beam is stressed to its ultimate strength on both the compressive and tensile sides just before failure occurs. According to his theory, the distance from the neutral axis to the fiber that fails first is

$$X = \frac{I}{C + T} d$$

where C and T are the ultimate strengths in compression and tension and d the depth of the beam. As a result of this theory the moment of resistance of a rectangular cast-iron beam is

$$M = \frac{5}{18} S\, bd^2$$

when the ratio of the ultimate strengths, $\frac{C}{T}$, is equal to 5. This equation may also be written

$$S = \frac{MK}{bd^2}$$

where S denotes the ultimate strength of the material in tension.

13 Emery[4] claims that neither Hook's law nor Bernoulli's assumption are true for cast iron, that the medial portion between the neutral axis and the extreme fibers is stressed more than assumed by Bernoulli's assumption, which would necessarily relieve the outer fiber of a certain amount of stress. In devel-

[1] Hodgkinson: Experimental Researches on Cast Iron.
[2] Phil. Mag. 1855.
[3] Trans. Am. Soc. C. E., Vol. 35.
[4] Trans. A. S. M. E. Vol. 8.

oping a formula for the resistance of a rectangular cast-iron beam he assumes the elastic law,

$$\Delta = KS^m$$

for the tension side and Hook's law for the compressive side, which gives

$$M = S\,bd^2 \frac{\left(n + \frac{2\,m}{3}\sqrt{2\,m\,t}\right)}{\left(1 + \sqrt{2\,m\,t}\right)^2}$$

where S is the tensile strength of the material, n and m are constants from integration and t the ratio into which the neutral axis divides the depth of the beam. This equation may also be expressed

$$S = \frac{MK}{bd^2}$$

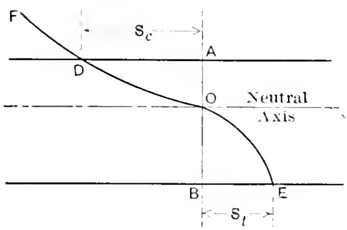

Fig. 1 Stress-Strain Diagram for Tension and Compression

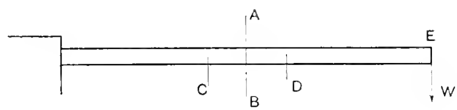

Fig. 2 Cantilever Beam Subjected to a Bending Moment

The values of K given by Mr. Emery range from 2.8 to 4.

14 Clark's formula,

$$S = \frac{WL}{1.55\,bd^2}$$

gives a value of $K = 3.46$.

15 Keep[5] published the results of a great many tests of different-sized specimens made of different grades of cast-iron and concludes that the silicon content and the rate of cooling greatly affects the strength of cast-iron. He also points out the fact that there is definite relation existing between the shrinkage and the percentage of silicon, and by measuring the shrinkage of a bar, the silicon content may be found from his shrinkage chart. This same chart is also provided with curves from which the strength of any bar between $\frac{1}{2}$ in. and 4 in square may be found when the strength of any other bar within these limits is known. In the discussion of Mr. Keep's paper, Professor Benjamin proposed the formula

$$W = H\frac{b^{0.83}\,d^{1.89}}{L^{1.058}}$$

[5] Trans. A. S. M. E. Vol. 17.

where W is the breaking load and H a constant determined by breaking a bar 1 in. square and 12 in. long.

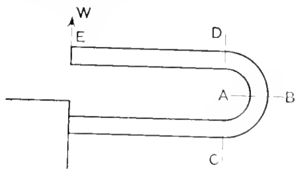

Fig. 3 Bent Cantilever Beam Subjected to a Bending Moment

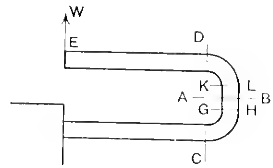

Fig. 4 Bent Cantilever Beam Subjected to a Bending Moment

16 Although based upon different theories and experiments, most of the above formulæ for straight cast-iron beams of rectangular cross-section reduce to the form

$$S = \frac{MK}{bd^2}$$

For rectangular sections the value of K has been found to vary between 2.8 and 4, depending upon the elastic laws of the material when subjected to tensile and

Fig. 5 Straight Beam Subjected to Bending Load

compressive stresses; and these laws vary with the sectional area, chemical composition, temperature of the metal when poured and the rate of cooling.

EFFECT OF CURVATURE AND FORMULAS FOR CURVED BEAMS

17 In Fig. 2 the simple cantilever beam is subjected to a bending moment due to the load W supported at the end. The bending moment at the section AB is resisted by the tensile and compressive stresses in the upper and lower fibers of the beam.

18 Consider the beam when bent into the forms shown in Fig. 3 and Fig. 4. The condition of stress in the portion ED is not affected by the change in shape; whereas the section AB resists not only the bending moment due to the load, but an additional force due to the direct pull of W.

19 The stresses in any section of a straight beam subjected to a bending load W, and a tensile load W' as shown in Fig. 5, may be accurately represented by the well known formulæ,

$$S_t = \frac{Mc}{I} + \frac{W'}{A}$$

$$S_c = \frac{Mc}{I} - \frac{W'}{A}$$

20 These formulæ are supposed to be true for straight portions of beams only; but due to their simple form, they are often applied to curved sections such as AB in Fig. 3; in which case $W' = W$ and $M = WL$, where L is the distance from line of application of the load to the gravity axis. When used in this way these formulas assume that the neutral axis coincides with the gravity axis of the section and its position is not affected by the curvature of the beam. These formulas may also be written in the form,

$$S_t = \frac{W}{A}\left(\frac{Lc}{R^2} + 1\right) \qquad [1]$$

$$S_c = \frac{W}{A}\left(\frac{Lc}{R^2} - 1\right)$$

where R is the radius of gyration and equal to

$$\sqrt{\frac{I}{A}}.$$

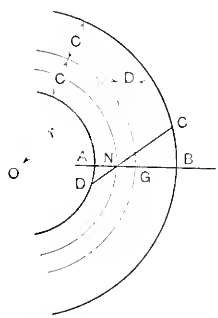

FIG 6 ENLARGEMENT OF CURVED PORTION FIG. 3

21 Fig. 6 shows an enlargement of the curved portion of the beam represented in Fig. 3. Assuming that a plane passed through the section AB before the load is applied remains a plane under the conditions of stress, that the stress is directly proportional to the distance from the neutral axis, and the radius of curvature of the gravity axis does not change; it will take less stress to deform the fibers on the convex side the same amount as on the concave side, because the convex side is longer. When the stresses at A and B are equal, the deformations may be represented by BC and AD respectively. The neutral axis does not coincide with the gravity axis at G, but passes through the point N which is nearer the convex or tension side, and at a distance D from G. The distance D, through which the neutral axis shifts, is independent of the stress when expressed by the equation.[6]

$$D = -\frac{\int \frac{y\,dA}{y + r}}{\int \frac{dA}{y + r}} \qquad [2]$$

[6] This method of analysis is due to Résal and is given in Strength of Materials by Slocum and Hancock.

where y denotes the distance from the gravity axis to any fiber having an area equal to dA, and r the radius of curvature OG of the gravity axis.

22 The stress on any fiber at a distance y from the gravity axis is expressed by the equation

$$S = \frac{M}{(y+r)} \frac{(y+D)}{\int \frac{(y+D)^2}{y+r} dA} \qquad [3]$$

where the bending moment, $M = W(L - D)$.

23 The application of the above formula may be greatly simplified by a geometrical transformation of the section as shown in Fig. 7. Let $KLMN$ represent a section cut by the plane AB in Fig. 3, OS the axis of symmetry passing through the center of curvature O and GP the gravity axis of the section perpendicular to OS. By drawing radial lines from O through each point in the boundary, such as T, cutting the gravity axis at some point R, the lines drawn through T and R, perpendicular to OS and GP respectively will intersect in the point E. The locus of the point E is the boundary of the transformed curve $klmn$.

24 It has been proven by Résal that the distance between the center of gravity G of the original section and the center of gravity G' of the transformed section is equal to the value of D given in Equation 2, and the moment of inertia of the transformed section is equal to the integral in Equation 3. By denoting the moment of inertia of the transformed section by I', the above equation reduces to

$$S = \frac{Mr}{I'} \cdot \frac{y+D}{y+r} \qquad [4]$$

25 Another method of analysis is that due to Pearson and Andrews which takes into account the change in the radius of curvature and decrease in cross-sectional area due to lateral deformation. The tensile stress on the concave side is expressed by the formula

$$S = \frac{W}{A}\left[\frac{L}{r\,\gamma_2}\left(\frac{1}{\left(1-\frac{c}{r}\right)^{n+1}} - \gamma_1\right) + 1\right] \qquad [5]$$

where

W = load in pounds;

A = area of cross-section in square inches;

L = distance from line of application of load to the gravity axis of the section;

r = radius of curvature of gravity axis in inches;

c = distance from gravity axis to extreme fiber on tension side;

n = Poisson's ratio of lateral contraction.

The value of γ_1 is determined graphically as follows: Let $KLMN$ in Fig. 8 represent the cross-sectional area cut by the plane AB in Fig. 3; r the radius of curvature, GP the gravity axis and y the distance from any point C on the boundary to the gravity axis. For each value of y, or position of D lay off

$$C\,E = \frac{C\,D}{\left(1+\frac{y}{r}\right)^{n+1}}$$

forming the boundary $klmn$. The area of $klmn$ divided by the area of the section $KLMN$ is equal to the value of γ_1.

26 The value of γ_2 is equal to

$$\frac{\text{area of } klmn\text{—area } k'l'm'n'}{\text{area of } KLMN}$$

where the boundary of the area $k'l'm'n'$ is formed by making

$$CJ = \frac{CD}{\left(1 + \frac{y}{r}\right)^n}$$

for each value of y.

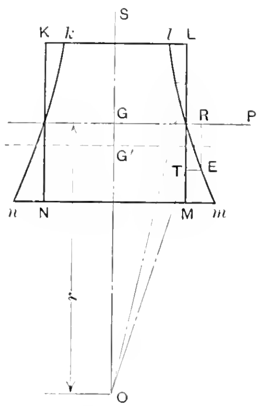

FIG. 7 DEFORMATION OF SECTION AB OF FIG. 3 WHEN UNDER STRESS

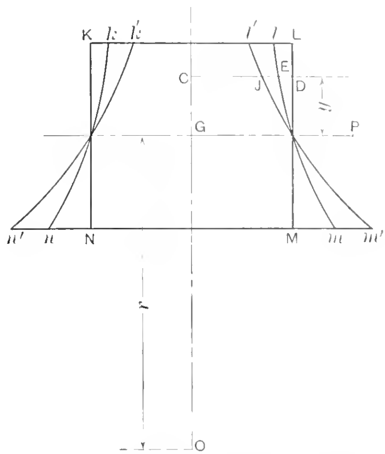

FIG. 8 DEFORMATION OF SECTION, UNDER PEARSON AND ANDREWS THEORY

27 The stress in any section of the straight portion of the beam shown in Fig. 3 may be found from the formula

$$S = \frac{Mc}{I}$$

and the stress in a section perpendicular to the line of application of the load, such as AB, may be found from Formula 4, provided the beam is of homogeneous material and obeys Hook's law, but none of the above formulas can be accurately applied to the section between A and C.

28 It is not necessary, however, to investigate more than one section of the curved portion provided the throat depth is small, as in the case of hooks; but in designing large punch frames it is desirable to determine at least two sections within the curved portion.

29 By comparing the properties of cast iron with the assumptions upon which the Formulas 1, 3, and 4 are based, it is easily seen that they do not apply to cast iron with any degree of accuracy. Hodgkinson's experiments

seem to show that due to the properties of the material, the neutral axis of a cast-iron beam shifts toward the compression side a distance

$$D' = \frac{d}{3}$$

Résal's formula as given in Equation 2 when applied to a rectangular section shows that

$$D = r - \frac{d}{\log_e \frac{2r + d}{2r - d}}$$

30 If the radius of curvature be such as to make $D' = D$, it seems that Formula 1 would apply. By equating the values of D and D' and solving, $r = 0.0505\ d$, which is a value that could not be used in practice. Hence, there is apparently no rational formula that represents the relation between the breaking load and the unit strength of curved portions of cast-iron beams similar in form to that shown in Fig. 3.

31 Press and punch frames requiring a wide gap are usually shaped similarly to the beam shown in Fig. 4, in which case a portion of the spine is straight. The sections KL and GH may be considered as belonging to either the straight or curved portions. If considered as belonging to the curved portion formula 4 should apply; but if taken as belonging to the straight portion it is subjected to the same conditions of stress as the section AB, and formula 1 should be applicable. These formulas, however, give different results which seem to indicate that the section AB should be less than the sections KL and GH of the curved portions, hence the condition of stress at KL and GH is somewhat similar to that due to sudden change in cross section, or which exists in the section connecting a spherical end to a thick cylinder.

32 A formula for determining the ultimate strength of castings having straight spines should recognize the change of the neutral axis due to the elastic properties of cast-iron. Such a formula based on the knowledge of straight beams of rectangular section takes the form

$$S = \frac{MK}{bd^2} + \frac{W}{A} \qquad [6]$$

where K is a constant to be determined experimentally.

33 The stress at sections between A and D in Fig. 3 and in sections above KL in Fig. 4 are usually determined by the formula

$$S = \frac{Mc}{I} + \frac{W \sin \theta}{A} \qquad [7]$$

where M is the product of the load into the distance between the line of application of the load and the gravity axis of the section considered; and θ the angle between the line of application of the load and the section produced until they intersect. For rectangular sections this formula may also be written

$$S = \frac{MK}{bd^2} + \frac{W \sin \theta}{A} \qquad [8]$$

FIRES: EFFECTS ON BUILDING MATERIAL AND PERMANENT ELIMINATION

By Frank B. Gilbreth, New York

Member of the Society

A remarkable paper, Bulletin 418, just issued by the United States Geological Survey, entitled The fire tax and waste of structural materialism in the United States, by Herbert M. Wilson and John L. Cochrane, contains the following astounding data:

The total cost of fires in the United States in 1907 amounted to almost one-half the cost of new buildings constructed in the country for the year. The total cost of the fires, excluding that of forest fires and marine losses, but including excess cost of fire protection due to bad construction, and excess premiums over insurance paid, amounted to over $456, 485, 000, a tax on the people exceeding the total value of the gold, silver, copper, and petroleum, produced in the United States in that year.

The actual fire losses due to the destruction of buildings and their contents amounted to $215,084,709, a per capita loss for the United States of $2.51. The per capita losses in the cities of the six leading European countries amounted to but 33 cents,or about one-eighth of the per capita loss sustained in the United States. In addition to this waste of wealth and natural resources, 1449 persons were killed and 5654 were injured in fires.

2 In discussing this waste, Charles Whiting Baker, editor of Engineering News, in an address before the meeting of the national engineering societies on the Conservation of Natural Resources, March 24, 1909, said:

The buildings consumed, if placed on lots of 65 ft. frontage, would line both sides of a street extending from New York to Chicago. A person journeying along this street of desolation would pass in every thousand feet a ruin from which an injured person was taken. At every three-quarters of a mile in this journey he would encounter the charred remains of a human being who had been burned to death.

The American Society of Mechanical Engineers, 29 W. 39th Street, New York. All papers are subject to revision.

The results obtained indicate that the total annual cost of fires in the United States, if buildings were as nearly fireproof as in Europe, would be $90,000,000, and therefore that the United States is paying annually a preventable tax of more than $366,000,000, or nearly enough to build a Panama canal each year.

It will be incidentally noted that fire protection involves the use of 2,000,000 tons of metal, having a value in excess of $127,000,000, and the metal in 350,000 hydrants, having a value of $30,000,000, all of which is wasted on account of the need of preparing to fight fires of a kind which, because of the inflammable character of building construction in this country, would develop into conflagrations without adequate water service and fire departments.

The estimated cost of private fire protection, including capital invested in construction and equipment, aggregates about $50,000,000, and the annual interest on this sum and the annual cost of watchmen's services amount to about $18,000,000.

3 In this age of "conservation" it is amazing that so little has been done to prevent destruction by fire, and to apply the lessons that every great fire teaches us. The interest of the entire public in fireproof construction flares up with a great fire, but flickers out before the building permits for new structures are granted. The average owner when rebuilding even finds fault with the authorities whose duty it is to enforce the inadequate existing ordinances relating to noncombustible construction and to "fire-stopping" in combustible buildings.

4 There must probably be more big fires among buildings now built, but there is no sane excuse for any such loss in the buildings to be built in the future. Within the last six years there have been wonderful opportunities for studying great fires here in our own country. It has been possible to observe the destruction that occurred, to discover why it occurred, and to determine exactly what must be done if repetition of such destruction is to be prevented in the future.

5 The writer has been fortunate in being able to make careful observation of the great fires at Toronto, Sioux City, Baltimore, San Francisco, Chelsea and elsewhere. Having become interested in the effects of fires as observed in Sioux City and Baltimore, the observations in San Francisco were made with great care and detail. The ruins of each of the 503 city blocks in the San Francisco fire were visited and studied. This led to the formulation of definite conclusions which have since been again checked by the Chelsea fire. The conclusions here presented, therefore, are not the result of theorizing or reading only, but of painstaking and directed observation.

6 All great fires are alike. Building material behaves the same

in a fire regardless of the location. We will therefore study a typical building in a typical fire.

7 The building of the Mutual Life Insurance Company at San Francisco was a steel frame structure, eight stories high, of the best construction in 1892, when it was erected. The laying up and filling of the joints in the brick, stone and terra cotta were as nearly perfect as possible. The exterior wall completely enclosed the steel frame, which was put together with bolted connections. The floors were of hollow terra cotta flat arches, and the partitions were hollow terra cotta blocks. The damage to the building, which necessitated the removal of the upper six stories, was practically all done by fire.

8 This building is excellent for an illustration, because it shows the good and bad points of many different kinds of incombustible materials, which were used in its construction. We took it down after the fire, photographing every part as it was taken down.

9 Examinations while taking down a building give the ideal method of studying the cause and effect and possible remedy for damage by fire.

10 The pictures illustrate better than could any description the process and the stages of removal. They show also that a very small quantity of wood in a so-called "fireproof" building built almost entirely of non-combustible materials will furnish sufficient heat to destroy it. The lessons from this and from all fires point to these conclusions: *No structure of the future should be built of wood. No structure of the future should contain any wood.* It has taken costly lessons to teach us this, but if we have at last learned the lesson, the price we have paid is cheap.

11 It has long been realized that, with the wood supply of the world constantly diminishing, wood was bound to become too expensive to use as a building material. But it is not so widely realized that the day when wood is as costly as non-combustible building materials is *here.* Today, concrete structures, and in some localities other non-combustible structures, can be erected at no greater first cost than wooden ones; with an added element of safety to those who use the building which cannot easily be overestimated.

Cost of Concrete Construction

12 In order to hold the place it claims—that of the cheapest and best fireproof construction material—concrete must be able to show itself cheapest in first cost, as well as cheapest in the long run.

13 Concrete materials are obtainable everywhere: stone, ledges, gravel, sand, burnt ballast, slag, brick refuse, terra cotta chips, stone cutters' refuse and cinders, are all good aggregates for concrete.

14 As far as the cost of the labor of putting the material in place is concerned, much has been done toward reducing that to a minimum. With metal forms and certified concrete, concrete construction is cheaper today than that with brick, hollow terra cotta tile or any other material.

15 Charles T. Main, a member of the Society, has recently published the most valuable contribution regarding cost data of brick and wood mill construction. Mr. Main is a leading authority on this subject, and his data are conceded to be correct. Mills have been built entirely of concrete, in all parts of the country, in less time than it is possible to build them of brick and wood and for less money than the square foot and cubic foot prices collected by Mr. Main. A few years ago this statement would not have been true. Today, with the aid of new designs, new methods, new forms, scientific grading and proportioning, it is a fact that cannot be disputed, but one, nevertheless, not generally known.

16 The development of the entire concrete building and of the parts of the concrete building have been slow, because it has taken a long time to learn to *think* in concrete. Each student brought his stock of experiences from another field to bear on the problem, but the problem was so new that few could understand it in all its aspects. The engineer, who knew how to design the strength, knew little about artistic features. The architect, who alone could give beauty to the building, was not an expert in the methods that make low costs. Progress was made more difficult by the fact that so few of the structural features and construction methods were standardized.

17 The contractor, having analyzed his costs, saw that the forms were the largest single item in the cost of the concrete. This fact had its effect on the design of the concrete building, in the trend toward straightway repetition form work and flat-slab ceilings, with as little beam and girder work as possible. A further benefit was in the fewer corners for fire to attack or for interruption of the action of sprinklers, saving also in the cost of the sprinkler system.

18 After the flat-slab ribless type of ceiling, with its low cost of forms, came standardization of the units of forms for walls and columns. With the use of these metal form-units a new problem faced us, namely, slight modification of design to agree with the cheapest labor requirements of the metal forms. The influence was

also felt, of the fire protection design thoroughly worked out and standardized by Charles L. Norton, professor of heat measurements at the Massachusetts Institute of Technology and engineer in charge of the engineering experiment station of the Factory Mutual Fire Insurance Companies. Mr. Norton's recommended practice, which is now universally accepted, is so simple and apparently so obvious that we sometimes forget to give him the credit for his work.

19 The importance of the forms, from the standpoint of economy, in being able to build fireproof buildings for the price of brick and wooden mill construction, is clearly shown by the fact that Charles D. Watson, of Syracuse, N. Y., on account of the reduction in the number and expense of forms, has been able to build a number of buildings from separately cast members and reduce the costs below anything ever cast *in situ* in wooden forms.

USE OF METAL FORMS

20 We come now to the latest developments, the metal form-units that have been perfected, densifiers for compacting the concrete, mechanical conveyors for displacing the wheel-barrow and hand tamping, and the concrete-producing factory, centrally located. These things have all arrived. Metal molds have reduced the price of concrete to that of wooden construction.

21 For the greatest saving in the cost per cubic foot of the completed building, the methods of construction, as well as the designs, must be standardized. This is rapidly being done. For example, the metal forms are set up and concrete is hauled in large quantities from a centrally located factory and poured at once for the entire story of a building. This does away with the joints between the work of two different days, and permits of figuring the tensile strength of the concrete in design calculation, with a great consequent saving of reinforcement. Such calculations cannot be safely figured unless the whole story is poured at once.

BEARING ON ULTIMATE COST OF HEALTH CONSIDERATIONS

22 Figuring the cost of furring, lathing, plastering, interest, fixed charges, heating, and repairs, concrete is certainly cheaper than wood. If you also figure health, concrete is *very much* cheaper. A concrete building is cooler in summer and warmer in winter than any other kind. It can be cleaned out with a hose. It can be easily, quickly and thoroughly fumigated, room by room, or all at once. It is drier

than any other, provided it is built with self-ventilating air spaces in all of the exterior walls. A concrete building is vermin-proof, and should germs or vermin get in the building, it may be easily rid of them.

23 The 1907 Year Book of the Department of Agriculture says (Page 98):

> No one of our wild mammals, possibly not all combined, does as much damage as the common rat. . . . .
>
> The rat continues to cause great losses throughout the United States. During the past year an attempt was made to ascertain the approximate damage done to property by this rodent, in the cities of Washington and Baltimore. Many business men were interviewed, including dealers in various kinds of merchandise, feeders of horses, managers of hotels and restaurants, and manufacturers. The inquiries included all sections of the two cities, and both small and large dealers. Data were obtained from some six hundred firms and individuals, from which it was estimated that the annual loss from rats in Washington is about $400,000; in Baltimore, upwards of $700,000. Assuming, as is probable, that similar conditions obtain in all our cities of over 100,000 inhabitants, the damage by rats in these centers of population entails a direct loss of $20,000,000 annually. This enormous sum gives an idea of the still greater total loss inflicted by this rodent throughout the length and breadth of the land.
>
> The rat continues also to excite grave apprehension, because of its agency in distributing the dreaded plague and other diseases. Boards of Health and the Marine Hospital Service in several of our maritime cities have been prosecuting active war against the rodents, and large sums have been expended in efforts to effect their extirpation. No one method has proved adequate, and only by concerted, systematic, and persistent efforts is it possible to reduce and keep down their numbers. The rat-proof construction of buildings, the constant use of traps, and the use of poisons wherever possible, will go far toward assuring public safety. Experiments with various poisons and mechanical means of destruction have been made during the year, and a report of the subject with recommendations will soon be issued.

24 If wooden buildings are to be tolerated because of their alleged low cost, consider then that the concrete structure furnishes no hiding places for the rats and mice that cause damage amounting to a large rate of interest on over a billion dollars annually. There is no danger in exterminating rats by wholesale poisoning in concrete buildings, for there are no cracks for them to crawl into and die.

Advantage of Concrete Construction in Elimination of Fire Loss

25 It may seem that we have wandered from our subject of fires and their permanent elimination, but it was necessary to show that concrete is thus, from *every* standpoint, cheaper than wood, its

only rival for low cost. Concrete construction is the best form for the elimination of fires, because it affords:

a Least cause for fires.
b Least amount of damage to structural parts by fire.
c Least amount of damage to structural parts by water.
d Least amount of damage to contents of building by water.
e Least quantity of combustible structural materials in a room.
f Least speed of combustion of the contents of a room.
g No concealed fires; all fires are in plain sight.
h Least spread of fire to adjoining parts of the same story.
i Least spread of fire to stories above.
j Least spread of fire to next buildings.

26 The causes of fires this paper will not discuss. The amount of damage done by a fire in a concrete building depends upon circumstances perfectly within our control and predeterminable. With concrete made of properly selected fire-resisting materials, practically no damage is done, except by prolonged high temperature. The results of recent tests by Prof. Ira H. Woolson, a member of the the Society, and his assistant, J. S. Macgregor, prove conclusively that a concrete building properly designed, with as few projecting corners as possible, will withstand long periods of the hottest hardwood fires, with no resulting damage that cannot be thoroughly repaired with mortar and a plasterer's trowel. These tests were on full-sized rooms with walls of concrete made of different kinds of material.

27 Concrete for walls can be poured in metal molds with sufficient accuracy to permit of painting or wall-papering without further plastering or smoothing. This means that the best of this fire-resisting material is brought to the very surface of the wall where the flames strike. With metal molds all corners can be made rounded as cheaply as square, or metal corner beads may, if desired, be inserted and retained in the molds. Now, if a fire does occur in a building made of concrete cast in smooth metal forms, the damage is less than in any other type of building and the danger of spreading is less.

28 A concrete building can be damaged by water less than any other form of construction. To begin with, water does not injure concrete; in fact it improves its quality. There is no wood to swell, and afterwards to shrink and crack the plastering. Even the paint best suited to be used on concrete lends itself particularly well to

washing down with water. There are no hollow spaces that the water can flow through, damaging the contents below. A concrete building is water-tight from floor to ceiling, and small quantities of water can be easily handled through small scuppers, either into the air space of the vaulted wall, or through the wall to the outside. The fire is never hidden by the construction; consequently no unnecessary streams of water are flooded into the building.

29 In a concrete structure there need be little or no combustible material. Let us take for example the dwelling house, for it is the most difficult to make both cheap and fire-proof. In a concrete residence there is little trim that cannot be made better and cheaper of portland cement than of wood. The chair rails and picture molding can be made of concrete. The trim around the windows and doors can be molded in metal molds as cheaply as straight members. Even the wire moldings can be done away with, and the conduits buried in the concrete partitions, walls, ceilings and floors. Baseboards should be made of concrete or else omitted entirely—as they serve no useful purpose in a concrete building, except in following wooden precedents. Windows may have cement sashes, with wired glass, and self-closing shutters, or self-dropping shutters of rolled-up metal or asbestos. Metal furniture may be used. The paint and varnish used on buildings and furniture should be selected carefully, as these are great factors in determining the temperature at which a fire will start and the speed with which it will spread. There is also a great difference in the paints and varnish used for painting concrete.

30 The flooring need not be of wood. There are many first-class non-combustible materials beside portland cement that will fill every good requirement of wood and still be fireproof. There are also parquetry floorings, made of slow-burning wood, and much thinner than the old-fashioned hardwood floor, which make the best flooring in case wooden floors are desired. In a concrete residence there is no excuse for wooden under-flooring nor for wooden screeds.

31 The best form of construction for the elimination of fires is one that keeps the fire in plain sight, once it is started. One of the greatest obstacles in fighting fire in wood construction is the difficulty of locating a fire after it is known to exist. Every second of time lost gives it accelerated fury. Holes cut through the walls, floors and ceilings to locate a fire oftentimes only furnish more drafts to feed the flames.

32 With hollow concrete blocks, or monolithic cast-in-place walls

and partitions there are no chances for the fire to be concealed. There is no cause for cutting into the partitions, floors or ceilings. There is no damage to the structure from cutting, no injury from water. With such a building, if a fire does start, it starts in plain sight remains in plain sight at all times and can be attacked instantly before it has spread; and the water damage will be practically nothing. Fires in plain sight are usually extinguished before the arrival of the fire department.

Checking the Spread of Fires

33 The spread of a fire into adjoining parts of the same story is possible in a concrete building only through doorways, pipe holes, etc. A concrete wall is an ideal barrier to the spread of any fire. Not only is it incombustible, but it is unaffected for a long period by any but extremely high temperatures. Its coefficient of expansion, 0.0000055 to 0.0000060, is practically the same as that of steel; consequently, there is no damage from unequal expansion of the concrete and its steel reinforcement. As for doorways, any of the makes of fireproof doors and windows well made in accordance with the requirements of the Boston Mutual Fire Insurance Company will stop completely almost any fire. There are metal-covered doors made that very few people can distinguish without touching from mahogany or other hard woods. These doors will confine any ordinary fire to one room in a concrete building; or they will hold any fire in one room long enough to enable the fire to be handled after it has got by the door.

34 The spread of fires in the same story is very slow compared with the spread vertically. Fire may be communicated from one story to anotner by means of well-ways, stairways, or holes in the floors, or by the fire passing out of a window on one story and in at the window above. In a concrete building, the floor forms an ideal fire stop even if the walls have been furred or lathed with wood.

35 There are so many good and cheap metal lathings and furrings on the market today that wood should be prohibited everywhere. While metal does cost more, in the long run it is cheaper to use. With vaulted concrete walls there is no real need of furring or lathing. Concrete construction is particularly well adapted to plastering directly upon the concrete. Furthermore, only one coat is needed to make the same quality of work as two or three coats upon wood or steel lathing. When the plastering is put directly upon the wall, there is no space in which the fire can travel.

36 The regular openings can be protected in the accepted way, and kept free from combustible contents.

37 The spread of a fire to the next building is caused by the combustible gases distilled by the heat from the paints, and varnishes, and even from the wood itself. This explosion (which firemen call hot-air explosion) sets the building on fire in several places at once. While the contents of a concrete building may burn, such a fire will not ordinarily make heat enough to cause the fire to jump wide spaces between buildings. As a further guard the best window, whether translucent or transparent, is one of wired glass. The wires should extend out from the glass sufficiently to be embedded in the concrete sash, holding the glass in place, even when it is heated to a point where a sash of other material would drop the glass or where the glass would fold down and lose its former shape.

38 The disuse of wood in building construction will mean:

- *a* Saving of forests.
- *b* Uninterrupted business.
- *c* Saving of life.
- *d* Saving of buildings.
- *e* Saving of the contents of buildings.

Government Aid in Advancing Fireproof Construction

39 The work to be done to reduce fire losses to a minimum is so great and so important that it can never be thoroughly and completely done until the Government takes it in hand. The Government could aid fireproof construction in various ways.

- *a* By passing laws restricting the use of wood in buildings.
- *b* By levying taxes, discriminating in favor of fireproof houses and against wood in construction.
- *c* By educating the people by Government documents on how to build fireproof houses.
- *d* By establishing a Government bureau for disseminating information regarding honest unbiased fire tests on material, together with Government experiments on different full-size buildings,—kinds, types, materials, etc.—with bulletins of the progress. The cost of this would be but a trifle compared with the benefits. There are several men specially qualified to advise on this work,

as they have been doing such work in their own laboratories for years.

e By building fireproof houses for the use of Government Departments and disseminating information concerning them by means of bulletins.

40 In the meantime, prize competitions would cause special investigation and study in all parts of America for the best house. A few attempts at such competitions have been made in the past. The judges have generally awarded the prizes, in accordance with their best ability, to the designer whose plan pleased them the most. Instead of this, the award should have been made to the competitor who could show the lowest cost per cubic foot, for the finished house with certain specified fireproof requirements. After the standard requirements of a house have been fulfilled, and developed in accordance with the best scheme of fire protection, durability, low cost, permanency speed in building, and comforts in winter and in summer, it is then time to add those beautifying effects that are so necessary from an art standpoint. Such a competition would show to the amazement of many that a better house can we build more cheaply of incombustible materials than of wood.

CONCLUSIONS

41 The only excuse for using wood construction is its low cost. Today—here—now—we have an incombustible material, a material at a less cost than wood that has stood and will stand high temperatures for long periods without injury. Wood must not be used. We do not argue that no other non-combustible material shall be used, and that concrete shall be used exclusively. There are many cases where other non-combustible materials have special merits. They should be used when it is advisable to do so. But now that we have a cheaper and incombustible substitute for wood wood construction, wood trim and wood finish should be legislated and taxed until wood is eliminated from all building construction.

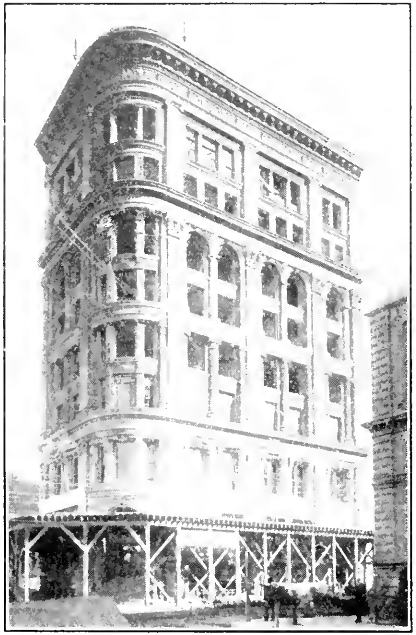

FIG. 1 WEST ELEVATION

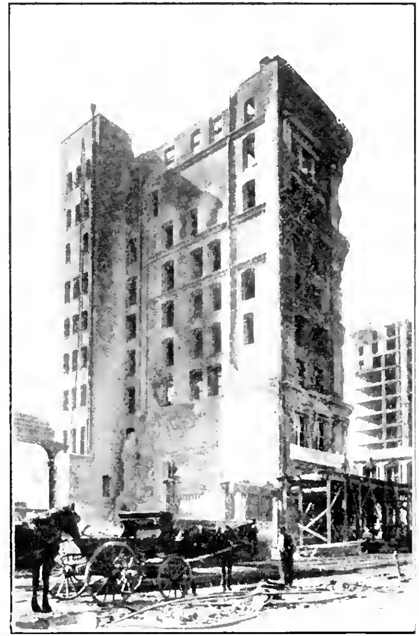

FIG. 2 EAST ELEVATION

Note that the granite was ruined where flames came out at openings. Where the draft was inward, the granite was in perfect condition. The ornamental terra cotta, though apparently but little injured, was completely ruined by heat cracks. Note crack entire height of building, visible in cornice (Fig. 1), showing line where bolts were completely sheared at each story by expansion due to heat.

Cracks extending from top to bottom, about on a line with the clay flue (Fig. 2) mark the location where the bolts sheared. Note also the cracks in the east wall at the fifth-floor level.

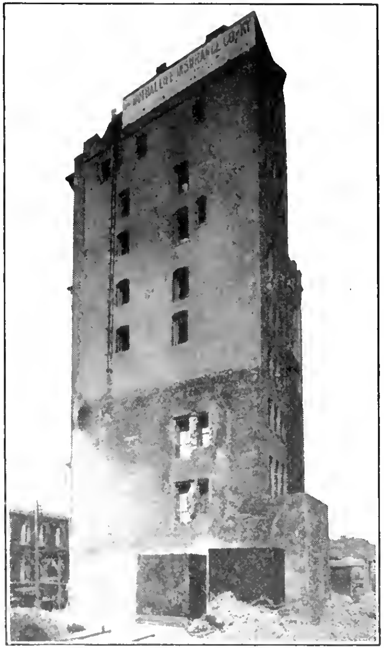

Fig. 3 South Elevation

Showing complete destruction of adjoining buildings.

Fig. 4 Fallen Roof Truss

Structural columns in top story pulled out and broken.

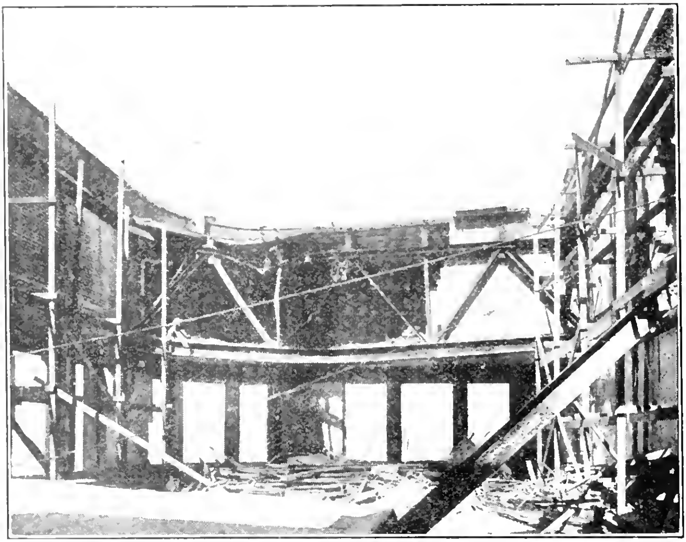

FIG. 5 VIEW LOOKING NORTH IN TOP STORY

Note the complete destruction of the roof trusses and various kinds of material, and that the wooden flagpole was not even scorched.

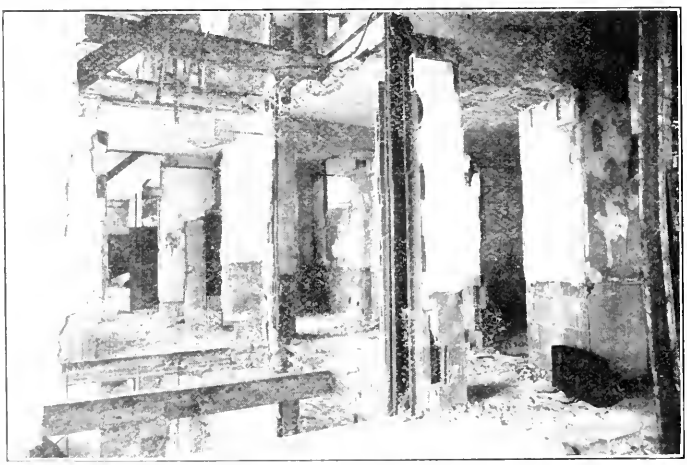

FIG. 6 DAMAGE TO ELEVATOR FRAMING

Although the only combustible material in this building was the wooden trim, floor boards, screeds and furniture, there was sufficient heat to warp the cast iron around the elevators out of shape and to burn up the contents of the steel vaults which were in nearly every room.

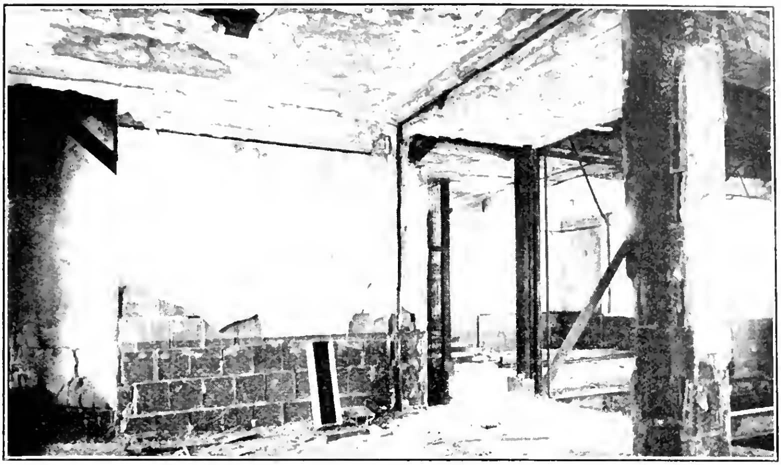

FIG. 7 DESTRUCTION OF NON-COMBUSTIBLE MATERIAL

In all these pictures the columns having pipes buried behind the fireproofing have variably had the fireproofing pushed away from the columns, due to the expansion of the pipes by heat. Note the complete destruction of the marble dado.

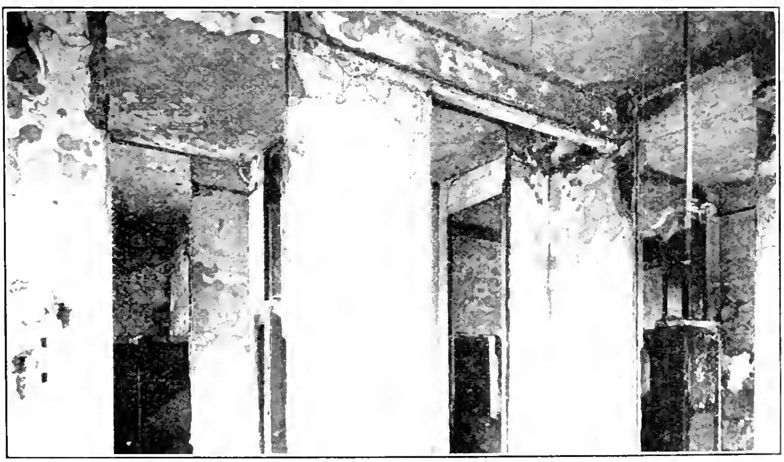

FIG. 8 COMPLETE DESTRUCTION OF PLASTERING

No kind of plastering has been found to stand the heat of such fire as occurred in this building. Even the plastering that remained upon the wall would not have been strong enough to repair with additional coats.

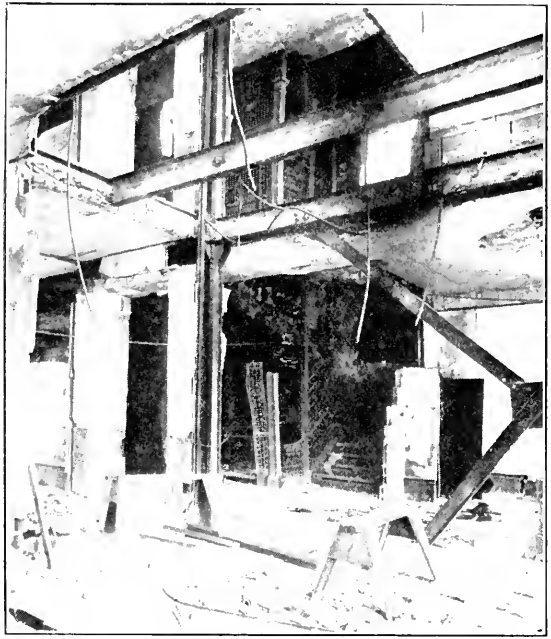

FIG. 9 LARGE HOLES IN FLOORS

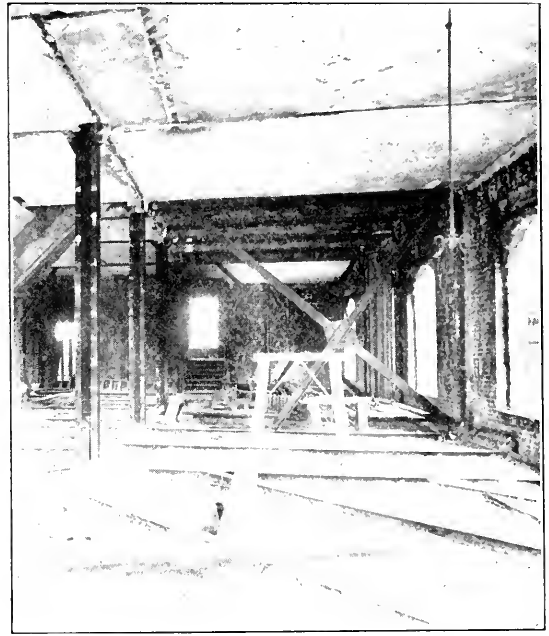

FIG. 10 VIEW OF SIXTH STORY

The large opening between floors (Fig. 9) was caused by structural steel in the roof falling through to the basement.

Fig. 10 is a typical interior view after partitions, cinder concrete fill, and all rubbish had been removed. The bricks in the walls were practically uninjured. The cinder concrete had no strength whatever. The hollow terra cotta floor tile slumped continually, necessitating walking on plank and beams instead of on the floor arches.

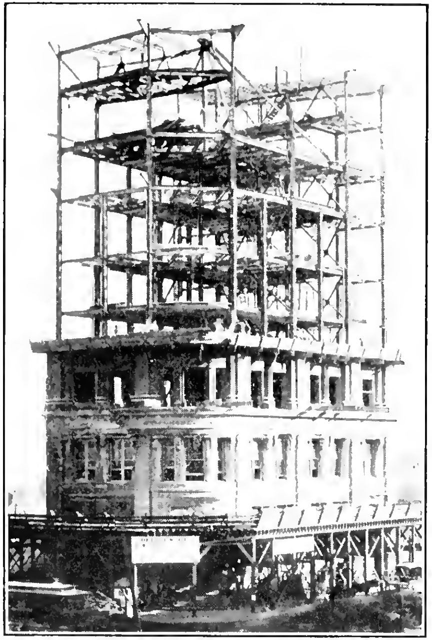

Fig. 11 North Elevation

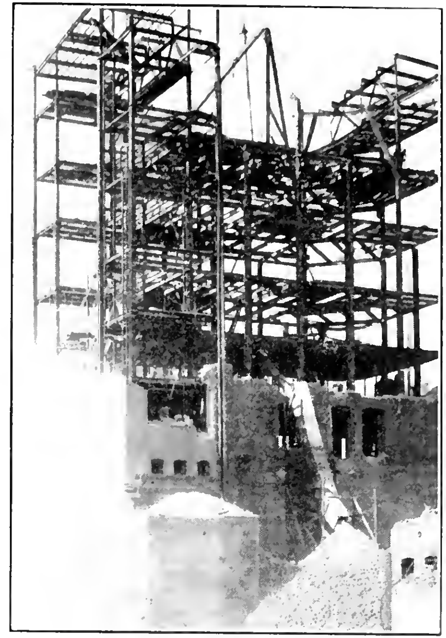

Fig. 12 East Elevation

Steel frame stripped to fourth story. Adjoining two different columns the entire height of the building (Fig. 11), connections had to be rebolted as fast as the work was taken down, asthe bolts were sheared by expansion of the brick walls.

The pile at the left (Fig. 12) shows brick that were sold and used again in new buildings. The rubbish pile of broken bricks, mortar, ornamental and structural terra cotta, cinder filling, etc., was about equal in size to the salvage. The steel below the eighth floor was uninjured. It was sold and used in other buildings in San Francisco.

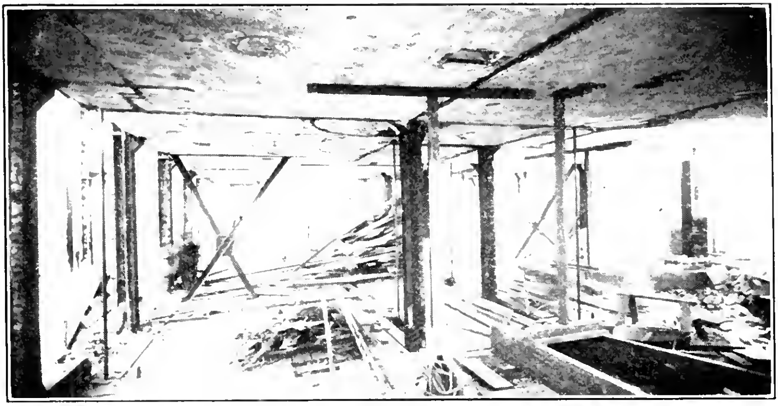

FIG. 13 DESTRUCTION OF FLOORS

The small holes in the ceiling were caused by workmen slumping through. The floors were so completely ruined by the heat that it was necessary to cover the third floor with plank to the depth of 18 in., to prevent accidents to the people in the lower stories from the slumping of the floors in the upper stories.

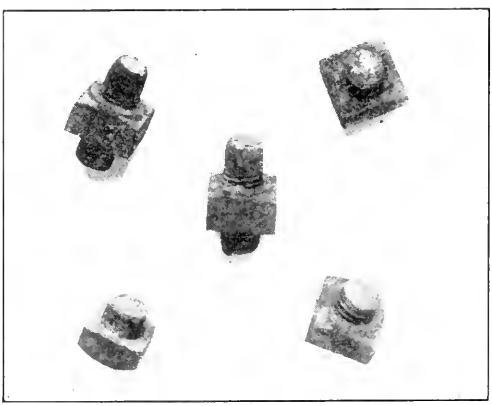

FIG. 14 SAMPLES OF BOLTS SHEARED BY EXPANSION DUE TO HEAT

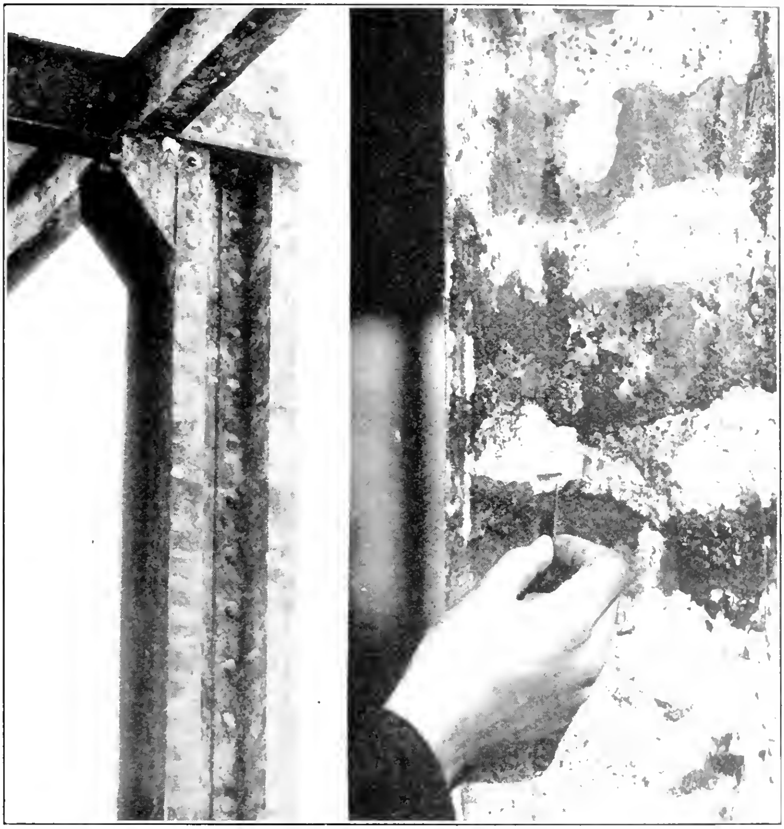

Fig. 15 Condition of Steel Frame

The left side of cut shows a typical exterior floor and column connection. The steel bears no signs of injury or disintegration, although buried in the exterior wall fourteen years. Fire had no effect on the steel, except warping where the frame was not properly protected by fireproofing, but there were several small places, such as that shown on right side of cut, that showed bad rust spots. Each of these cases appeared in steel buried in exterior walls. The rust spots appeared to be places that were not properly cleaned from rust at the time the columns were painted, and were imperfectly surrounded by brick mortar.

THE MECHANICAL ENGINEER AND THE TEXTILE INDUSTRY

By H. L. Gantt, New York
Member of the Society

The textile industry enjoys the distinction, to a greater extent, perhaps, than any other, of having been brought to a high state of perfection without the aid of the mechanical engineer. The machinery was developed by the mechanic before the mechanical engineer became a very important factor in the industrial world, and the plans were, and are still, built by mill architects, who as their name implies are architects rather than engineers. The most important field of this industry that the engineer has entered, is the power department, and in this field he has done much good work. The complicated and delicate machines for working cotton fibre, however, which are wonders of mechanical skill, have been brought to their high state of perfection by men who were mechanics rather than mechanical engineers. The operation of these machines, until recently, has been directed by men whose training was exclusively that of the factory, and who could solve well a concrete problem.

2 In this industry there is, as a rule, a wider gap between the financial interests that control, and the "help" that operate, than there is in almost any other industry.

3 The textile schools are today doing much to fill this gap by supplying to the mills educated men who, while understanding the detail operation of the machines, are capable of comprehending the larger problems of management, and can thus form a link between the financial men that control and the mechanics that operate.

4 The lack of such men in the past is undoubtedly responsible for the fact that some of the processes which influence the subject of management more than they do the product, and which are easily susceptible of being standardized and done automatically, are

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still being done expensively and inefficiently by hand, and in a manner that causes much subsequent labor and expense that should be avoided. The solution of this problem belongs more particularly to the function of management, for the workman often does not see the influence of one process on a subsequent one in another department.

5 I refer, for example, to the process of handling cloth in a bleachery. In order to make clear the point in mind, it is necessary to explain that in the process of bleaching, cotton cloth is generally sewed together piece by piece and handled in the form of a rope, which is drawn from one operation to the next by means of rolls. This rope of cloth is subjected to the action of various liquids, being first boiled in an alkali and then washed. After being washed it is usually impregnated with acid (technically "soured"), and allowed to stand in a pile for some minutes to allow the acid to act. The methods of forming this pile and of withdrawing the cloth from the pile, are the operations to which I have special reference.

6 As the piling operation is repeated after each of several impregnating operations, the successive pilings divide the process into a series of separate and distinct stages with a loss of time between every two. The usual method of piling is as follows:

7 The cloth is drawn from the souring machine by an overhead roll, which drops it to the floor beneath. A boy stands on the pile of cloth and so guides it with a stick that it is piled in substantially uniform horizontal layers. When the pile has reached a size determined by the judgment of the bleacher (or the boy), the rope of cloth is broken at a seam and a second pile is formed. When in the judgment of the bleacher the first pile has stood long enough, the cloth is withdrawn and pulled through a washing machine into a bath of chlorine water (technically "chemic"), after which it is again piled in the same manner by a boy with a stick. The judgment of the bleacher as to the time cloth should lie in a pile after impregnation seems to be controlled by his temperament, or by tradition, rather than by knowledge, for we find that hardly any two bleachers have the same opinion as to how long the cloth should be subjected to the action of the acid; and the practice varies from a few minutes to twenty-four hours. As a matter of fact the acid does all its work in ten minutes or less, and no beneficial effect can be discovered by a longer treatment.

8 Inasmuch as it is necessary to pull the cloth from the top of a pile, the leading portion as it leaves the sour pile has been acted

upon by the acid a shorter time than that at the bottom of the pile.

9 The top of the second pile is attached to the bottom strand of the first pile, and the top of the third pile is attached to the bottom of the second.

10 As each strand of cloth usually goes through several pilings in the course of being bleached, the action of the bleaching liquors on any portion of the cloth would be alternately long and short, according as that portion of the cloth was at the bottom or the top of a pile. If the rope of cloth was always broken in the same place, the worst that could happen would be an unevenness in the bleach due to the difference in treatment. It frequently happens, however (and this is more often the case than not), that the rope of cloth is not broken in the same place; and when this occurs the various lots of cloth of which the rope is composed, which usually belong to different customers become almost hopelessly mixed. The expense of straightening out such a mix-up has usually been considered one of the legitimate expenses of bleaching. Add to this the fact that the piling boy often piles the cloth so carelessly that it tangles as it is pulled off the pile, and not only damages itself, but usually shuts down a portion of the plant for awhile.

11 If we also realize the fact that chlorine, or "chemic," not only forms a most unpleasant atmosphere to work in, but is actually injurious to the lungs, it would seem that some automatic piling machine which would hold the required amount of cloth and permit the leading end of the pile to be withdrawn would long ago have been devised. Inasmuch, however, as this is not a problem requiring great mechanical skill, but one requiring a somewhat different kind of knowledge, it apparently had never been attacked until the writer came in contact with it.

12 Fig. 1 shows the machine which has been developed to accomplish the result, and Fig. 2 shows the cloth as it is delivered to and withdrawn from the machine. The machine consists of an inclined chute, with upturned ends, and having a bottom composed of a series of independent rollers, freely revolving. The cloth is dropped into the tall stack, and falling on the rollers is carried by its own weight to the bottom of the incline. The incline is filled, and as the fabric rises in the receiving stack, the forward end of the pile is forced upward in the other end of the machine, from which it is pulled off at the rate at which it enters the receiving stack.

13 By making the chute of the proper length a pile of cloth of any size may be held, and the cloth may be subjected to the action of the

impregnating liquor for any desired time, all portions of the fabric receiving exactly the same treatment. Such action produces uni-

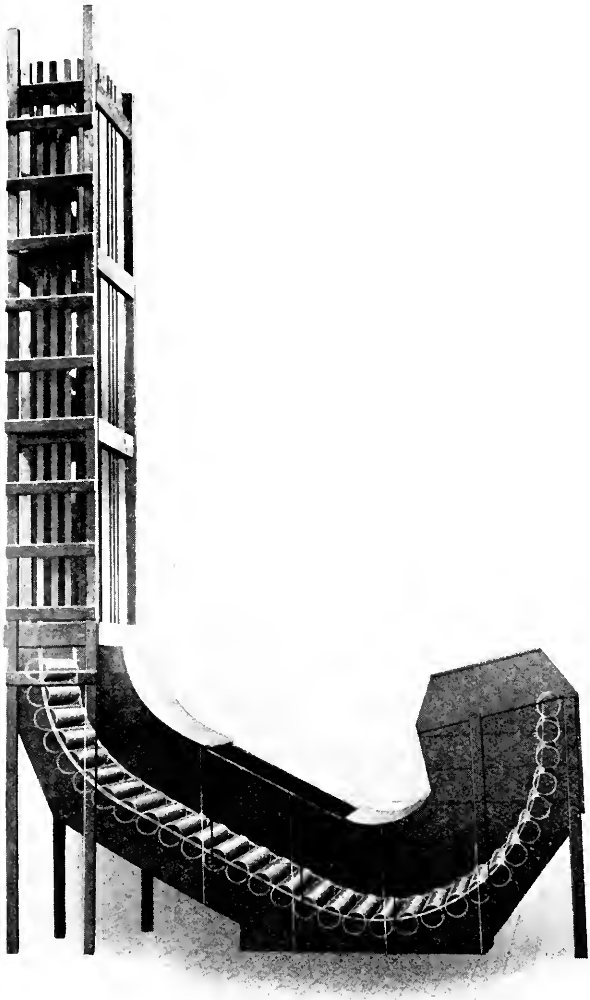

FIG. 1 AUTOMATIC PILING MACHINE

formity of bleach impossible under the old conditions, and as there is no need for breaking seams, the goods go through the bleach house in the order they went in, which produces a saving of expense and

worry realized only by the man who has operated under both methods. The straightening out of "mix-ups" and the "closing out" of "short lots" are the bane of a finisher's existence, and anything that reduces these troubles does much, not only to smooth the operation of the works, but to assure the customer that he is

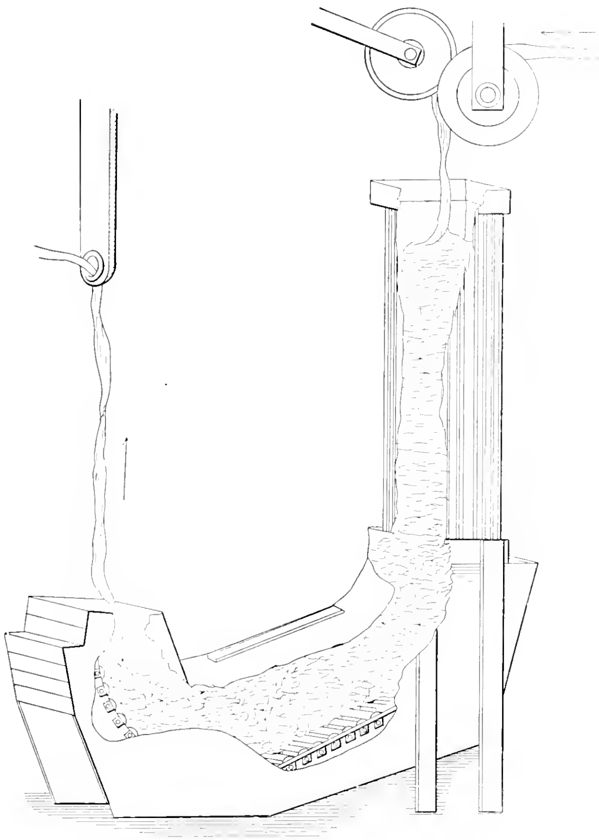

Fig. 2 Progress of Cloth through Machine.

getting back exactly the goods he sent. Moreover the dirt and damage caused by the piling boys are eliminated.

14 The saving in always having clean goods in uniform condition is greater than the saving in wages of the boys, and the relief to the foreman of having a smaller number of bleach-house boys to manage, makes it possible for him to devote his time to bleaching rather than to boys, with distinctly beneficial results to the bleaching.

15 In addition to the advantages already mentioned, there is a marked saving in time, for the cloth remains subject to the action of each liquid only the time needed to produce the desired result. Each piling machine takes the place of from three to four bins, and as it takes up less space than one bin, the saving in buildings is very con-

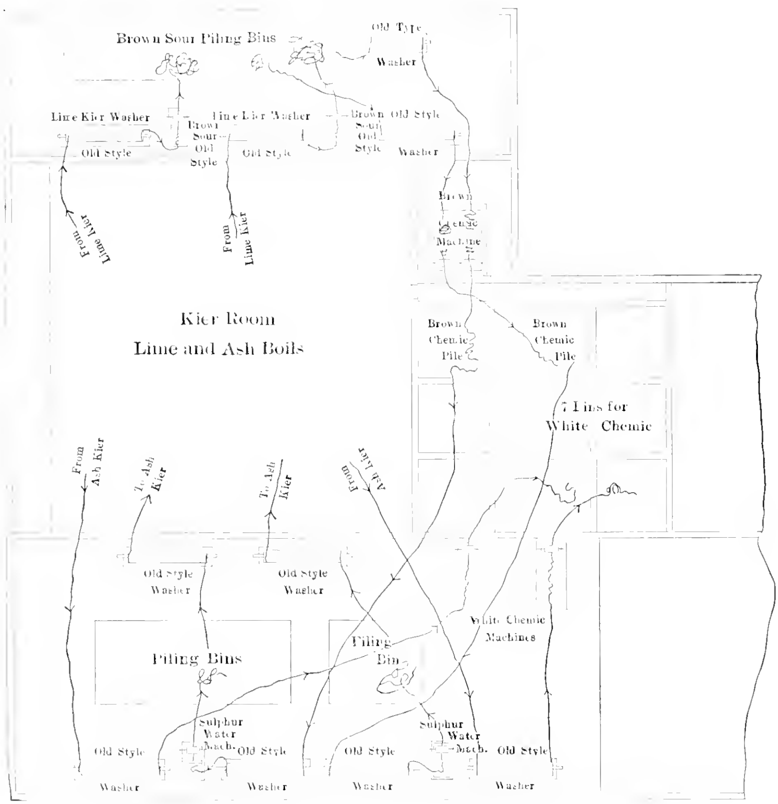

FIG. 3 ARRANGEMENT OF BLEACHERY (OLD SYSTEM).

siderable. In one case, when the washing, "souring" and "chemic" machines were rearranged in such a manner as to use a full equipment of piling machines to the best advantage, the saving in bleach-house space amounted to more than 40 per cent. Wherever the machines have once been installed it is obvious that they soon be come indispensable.

16 The fact that such an important operation can be taken care of in such a simple manner, is the best evidence that the writer entered

a field that has not been thoroughly investigated by the mechanical engineer. The field is still open, for plants are being built today to handle cloth exactly as it has been handled for fifty years. The builders of these plants have not yet discovered the function of the mechanical engineer, and are still putting their faith exclusively in bleachers.

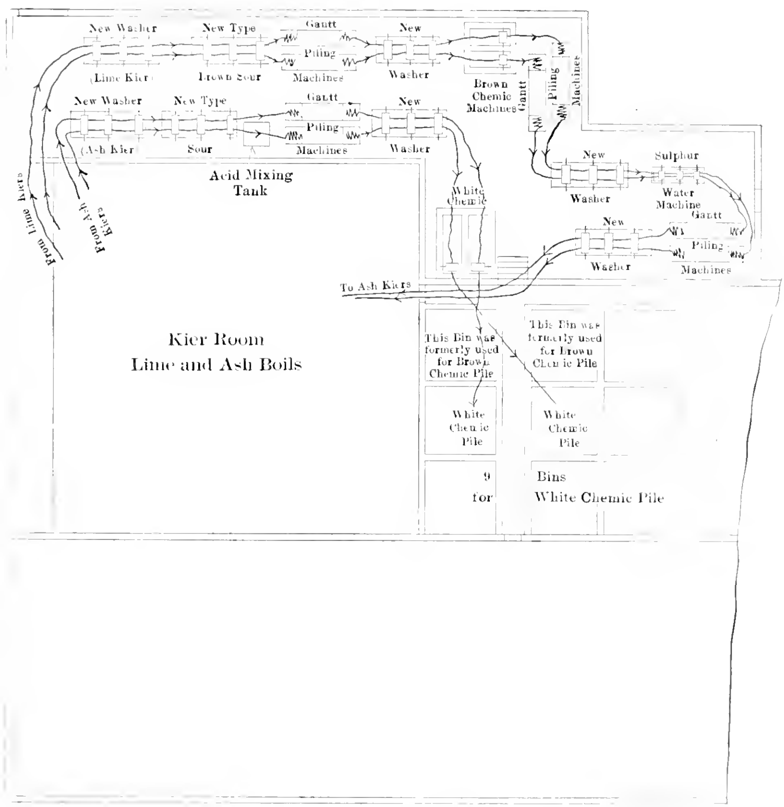

FIG. 4 ARRANGEMENT OF BLEACHERY (NEW SYSTEM).

17 Fig. 3 represents the course of cloth through a bleachery where the writer was told that the process had not been changed for fifty years. Fig. 4 shows the course of the cloth in the same bleachery after it had been equipped with piling machines, and other machines adapted to work economically with them. The new installation takes up less than 60 per cent of the space of the old and is operated by six people against the twenty people formerly needed.

18 The operations and their sequence are the same in the new as in the old lay-out, except for the installation of an additional "sour", which was thought desirable to remove the alkali of the second boil. The new lay-out is not a new method of bleaching, but simply a mechanical engineer's method of handling the old. There is hardly a bleachery in the country where the mechanical engineer cannot do similar work, and that without doing violence to the prejudices of the bleacher.

19 The standardization of bleaching methods must come later, and will take time, for we have here the habits of at least half a century to combat.

BALL-BEARING LINESHAFT HANGERS

By Henry Hess, Philadelphia, Pa.
Member of the Society

This paper is presented because of a request for more specific information made during the discussion of a paper that I was privileged to read at the Annual Meeting in New York, December 1909. That paper dealt with Lineshaft Efficiency, Mechanical and Economic, and was restricted to the presentation of actual measurements of the power consumption of the same lineshaft when mounted on plain and again on ball bearings, with that change the only variable.

2 It was the purpose of the paper to describe merely the actual test and its results, thus adding to the fund of available engineering knowledge. The favorable economic showing of the ball-bearing is inherent in the advantages of rolling as compared with sliding friction, quite aside from any particular make of ball-bearing; though if durability as well is to be secured, it naturally is essential that bearings of correct design and suitable workmanship and material be selected. The demand at the time of the discussion and since must serve as apology for such references to a product for which I am responsible as are incident to a description of the installation in question.

3 The first real improvement in hangers was made in this country by one of the oldest and most honored members of our Society. It was Mr. Bancroft who first mounted the box to swivel fully while well supported and who also gave it vertical adjustability. The means are so familiar to every one today as to constitute a commonplace. This original hanger was supplied with carefully fitted adjusting screws of liberal size; their ends terminated in correctly machined spherical sockets fitting over correspondingly machined spherical segments on the top and bottom of the box. Once adjusted in the hanger the box retained its place until a readjustment was demanded by some outside cause such as a settling building.

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4 Unfortunately the constant and incessant demand for lower and yet lower costs was given heed to by many until in course of time not a few of the many makes of hangers marketed are not machined at all but are foundry jobs throughout. Even so the consequent looseness and indefiniteness of position of the box supporting screws is not a very serious matter with plain bearings. The very length of the plain

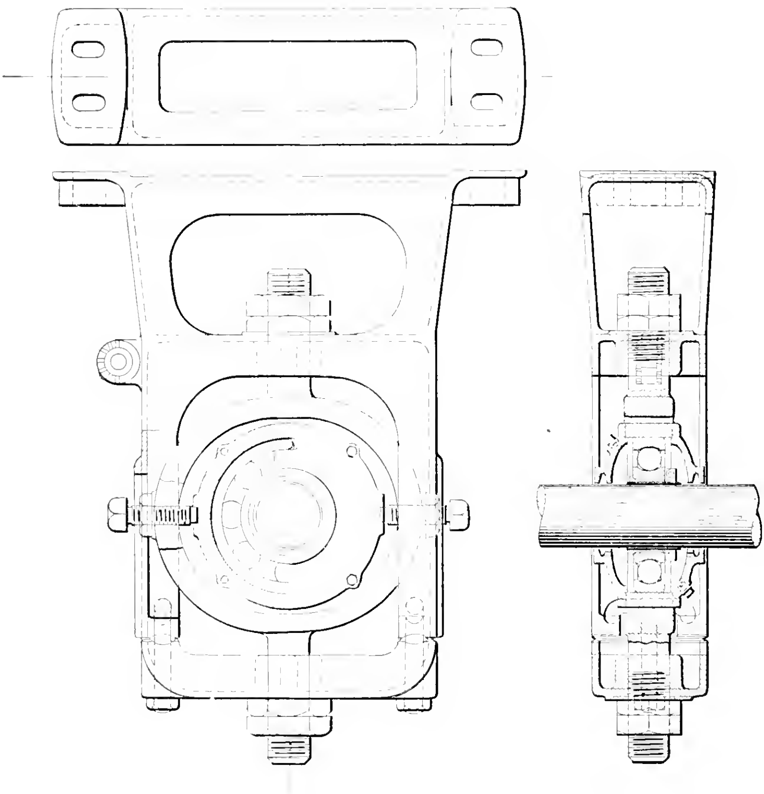

FIG. 1 ARRANGEMENT OF BALL-BEARING HANGER

bearing equal to some four or five shaft diameters helps to hold the box in line with the shaft if that is straight; or if the deflecting forces are too great, then the resultant excessive pressure on the plain bearings will draw attention to the trouble and by an insistent squeal, demand correction.

5 In first applying ball bearings to lineshafts I employed variou

hangers such as were on the market. The ball bearing was set in an enclosing box which in turn was held between the same supporting screws that supported the plain bearing displaced. Occasional reports were received that the power consumption was greater after the change than before. These were particularly insistent from a few installations where accurate meter records of electrical power consumed by the shaft driving motors were kept. Investigation finally disclosed in each instance a shifting of the shaft sections from their original alignment. The consequent and in several cases quite severe binding of the shaft at each revolution consumed considerable power. Owing to the very low coefficient of ball bearing friction, 0.0015, however, the additional load on the ball bearings was without evident effect and caused neither squealing nor even perceptible heating. Realigning the boxes immediately brought down the power consumption to the original low figure.

6 The Bancroft, or as they are better known, "Sellers" type hangers with their definitely machined supporting screws and sections of spheres on the outside of the box to rock on, was not found practicable with ball bearings, because these spherical sections became too flat with the large diameter of the box containing the ball bearing, as is evident from an inspection of the cross section of such a box given in Fig. 1.

7 It was finally and reluctantly decided to make up and build hangers, general coöperation with the specialists in that line having been found impossible from lack of interest, reluctance to make changes, the usual inertia resisting innovations, etc.

8 Many designs were laid out on paper and some tried, but again discarded as not responding to all of the following requirements of an ideal hanger:

a Definite support of the box on machined seats permitting no shifting under load.

b Ability of the box to swivel in all directions.

c Vertical adjustability of the box within the hanger body.

d Horizontal adjustability of the box within the hanger body.

e Rigidity in every direction, to permit the hanger to be used as a ceiling hanger, floor stand or post hanger.

f Convenience of adjustment in aligning the shaft.

g Adaptability for countershaft hangers involving a shifter-arm.

h Neatness of general outline and conformity to modern machine design by substituting box sections for ribbing.

i The lowest cost consistent with the other requirements.

9 The design finally evolved is shown in Fig. 1. The box is supported and pivoted horizontally on the ends of two screws tapped through the opposing sides of a yoke surrounding the box with enough freedom to give 1 in. of horizontal adjustment. This yoke has an upper and lower cylindrical stem, each turned to a running fit in the corresponding bore of the hanger; these stems are threaded and provided with nuts and checknuts and allow a vertical adjustment of 2 in. As the box can swivel horizontally in the yoke and that in turn vertically in the hanger the two together provide the desired universal swivelling freedom.

10 The hanger body is of channel section with the flat outside. The central crossbar that takes the weight of the box and shaft also materially stiffens the hanger. The lower crossbar is cast integrally with the hanger body and split off in the usual way. A single bolt at each end serves for attachment. This bolt is a drop forged T with the T turned down and ball ended to fit in corresponding sockets.

11 All of the various sizes, with the exception of the largest, which never comes into consideration for countershafts, are provided with cast-on lug with a serrated side face. To this may be bolted an arm of suitable length at any desired angle, to carry the usual eye guiding the shifter rod.

12 The construction of the bearing box is also apparent from Fig. 1, which shows it to consist of a central cast supporting ring bored to a sucking fit for the outer race of the ball bearing. To the side faces coverplates are bolted with an oil-tight joint and where these surround the shaft they are provided with a cored annular groove. The side lips are bored $\frac{1}{64}$ in. larger than the shaft diameter and have sharp edges.

13 This arrangement is found to be efficient in retaining the lubricant and so promotes cleanliness, while also preventing the entrance of ordinary foreign matter. For particularly difficult locations, as in cement mills, the very fine floating grit is kept out by a double groove, the outer one of which is filled with a fairly heavy grease. A single charge of heavy cylinder oil or non-acid grease will last the average lineshaft bearing several years; and to avoid total neglect refilling once a year is recommended.

14 The ball bearings are free endwise in the box. It is recommended that a lineshaft be held endwise by ordinary collars on either side of the central hanger so that all weaving endwise, due to expansion and contraction, settling, etc., is allowed for by the end freedom in the boxes. An occasional installation is found with heavy end-thrust, in which case the thrust is taken on one of the ball bearings by letting

it come up against the shoulders of the coverplates. Unusually heavy thrusts are provided for by special hangers into which a collar type of ball bearing is built.

15 As it is necessary to clamp the ball bearing to the shaft so that the inner race cannot rotate and as commercial shafting is somewhat indeterminate in size, a so-called "adapter" is employed, the details of which are shown in Fig. 2. The adapter consists of a bush fitting into the bore of the inner race, which in turn is fitted with a coned split sleeve. This latter is driven home endwise until the whole is tightly

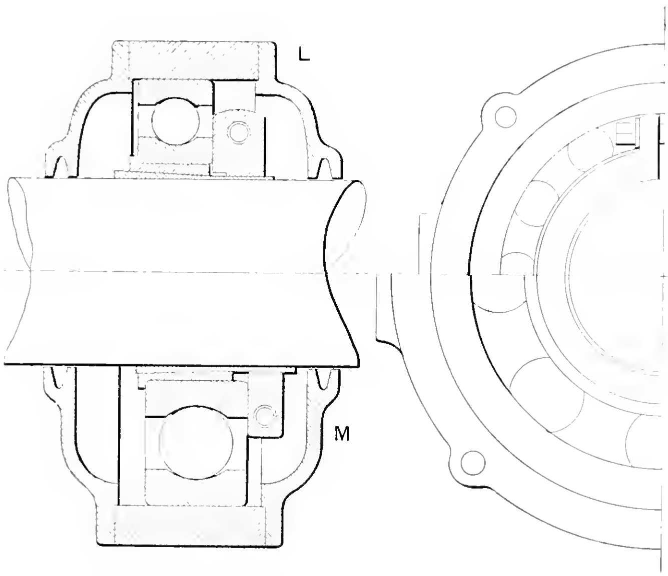

Fig. 2 Ball-Bearing Adapter

clamped onto the shaft retaining a truly concentric setting. Unless there is considerable vibration, the wedging effect of the small angle of the conical bush is sufficient to prevent any loosening, but to guard against all contingencies a split collar is clamped onto the sleeve with its face close up to the face of the bearing.

16 In the sectional view, Fig. 2, that part of the bearing above the center line appears narrower than that below, the first marked "L" and the latter "M." This indicates the relative widths of light-weight and heavy-weight bearings. Bearings of the "L" or light-

weight series take less load than those of the "M," or medium-weight, series. For all ordinary lineshafts the light-weight series is quite sufficient; it is only for extraordinary conditions or for jackshafts, etc., that the medium series comes into consideration. A single medium bearing is sometimes also used in the hanger next to the main belt.

17 The ball bearing itself is a very simple element, consisting, as is clear from both illustrations, of an inner race, an outer race, and a single row of interposed balls, running in grooves whose radius of curvature is only a few percent larger than the ball radius. Races and balls are made of alloy steels (a special mixture of the carbon, chrome, manganese variety).

18 These ball bearings are the same that are regularly supplied for the machine industries in general. Adapters for shafting range from $\frac{15}{16}$ in. to 3 $\frac{15}{16}$ in., both light and medium. As larger shafts are rarely of the nature of lineshafts it is preferable to fit seats directly to the bearing bore without the interposition of adapters.

19 In the paper referred to at the outset direct measurements were cited showing a saving in lineshaft friction of about 35 per cent under proper belt tensions of 44 lb. to 57 lb. per inch width of single belt and correspondingly more for heavier loads. The return on the investment was also shown to be 37 per cent per annum, taking into account the higher cost of the ball-bearing installation. Such higher cost is, however, not necessary. The initial cost may, in fact, be actually lower if in the original layout full advantage is taken of the possibilities of the ball bearing. The ball bearing is as safe and reliable at 600 r.p.m. as at 200; whereas, the use of such high speed with plain bearings is beset with so many difficulties in the way of reduction of size of lineshaft, pulleys, drop of hangers, etc., as to take that practically out of consideration for the average plant. The first cost of a ball bearing installation of 600 r.p.m. compares favorably with the first cost of one at 200 r.p.m. on plain bearings and the full advantage of the saving to be derived from ball bearings may thus be realized without any extra investment whatsoever.

20 In fact, the first cost of the ball-bearing equipment is quite likely to be less. As an example, it is fair to take a lineshaft such as that on which the test referred to in the December paper was made, but fully loaded to drive 32 machines. The installation elements that vary with the shaft speed are the shaft diameters, pulley diameters, hanger drops, belt widths and countershaft-driven pulleys.

The net cost of the installation material for the slow speed shaft of 200 r.p.m. on plain bearings transmitting 40 h.p. is...	$558.95
The net cost of the alternate installation for the high speed shaft of 600 r.p.m. on ball bearings is	441.87
The saving in first cost of material amounting to 21 per cent	$117.08

See Appendix for details.

21 The lineshaft bearing friction saving, based on an average coefficient of friction and confirmed by the series of tests cited in the previous paper, is 0.41 kw. or 1230 kw.-hr. for a year of 3000 working hours and worth, at 3 cents per kw.-hr., $36.90; secured by an installation 21 per cent lower in initial cost. See the Appendix for further details.

APPENDIX

COST OF PLAIN-BEARING SLOW-SPEED LINESHAFT MATERIAL

Shaft 200 r.p.m. in ring-oiling boxes, transmitting 40 h.p., driving 32 countershafts, one belt to each countershaft, 8 ft. to countershaft centers, countershafts 300 r.p.m.

10 hangers, 16-in. drop, ring-oiling babbitted boxes, net cost..........		$53.63
1 main pulley, 40 -in. x $12\frac{1}{2}$-in. double belt		
4 line pulleys 15 -in. x $6\frac{3}{4}$-in. single belt	4 counterpulleys 10 -in. x $6\frac{3}{4}$-in.	
4 " " $8\frac{3}{4}$-in. x $4\frac{1}{2}$-in. single belt	4 counterpulleys 6 -in. x $4\frac{1}{2}$-in.	
4 " " 10 -in. x $4\frac{3}{4}$-in. double belt	4 counterpulleys $6\frac{3}{4}$-in. x $4\frac{3}{4}$-in.	
4 " " $9\frac{7}{8}$-in. x $5\frac{1}{2}$-in. single belt	4 counterpulleys $6\frac{1}{2}$-in. x $5\frac{1}{2}$-in.	
4 " " $9\frac{3}{4}$-in. x $7\frac{3}{4}$-in. double belt	4 counterpulleys $6\frac{1}{2}$-in. x $7\frac{3}{4}$-in.	
4 " " $8\frac{3}{4}$-in. x $4\frac{1}{2}$-in. single belt	4 counterpulleys 6 -in. x $4\frac{1}{2}$-in.	
4 " " 10 -in. x $4\frac{3}{4}$-in. double belt	4 counterpulleys 7 -in. x $4\frac{3}{4}$-in.	
4 " " $12\frac{1}{4}$-in. x $4\frac{1}{2}$-in. single belt	4 counterpulleys 8 -in. x $4\frac{1}{2}$-in.	
	Net cost................	117.97
20-ft. 12-in. double belt		
320-ft. 3-in. single belt		
160-ft. 3-in. double belt		
80-ft. $3\frac{3}{4}$-in. single belt		
80-ft. 4-in. double belt	Net cost................	360.10
72-ft. $2\frac{7}{16}$-in. lineshaft	Net cost................	27.25
	Total net cost.....	$558.95

COST OF BALL BEARING HIGH SPEED LINESHAFT MATERIAL

Shaft 200 r.p.m. in Hess-Bright medium series ball bearings, transmitting 40 h.p., driving 32 countershafts, one belt to each countershaft, 8 ft. to countershaft centers, countershafts 300 r.p.m. Lineshaft pulleys reduced in diameter by one-half and the driven countershaft pulleys incerased in diameter by one-third; belts decreased in width in correspondence with the increased speed; lineshaft decreased in diameter proportionately to speed; under both conditions safe for 60 h.p. according to catalog ratings. Hanger decreased in drop to 10 in., rather more than the diameter of largest counterdriving pulley. Belts 50-lb. per inch width, single.

10 hangers, 10-in. drop, medium weight ball bearings, net cost			\$159.20
1 main pulley, 28-in. x $6\frac{1}{2}$-in. double belt			
4 line pulleys $7\frac{1}{2}$-in. x $4\frac{1}{2}$-in. double belt	4 counterpulleys 15-in. x $4\frac{1}{2}$-in.		
4 line pulleys 6-in. x $3\frac{1}{2}$-in. single belt	4 counterpulleys 12-in. x $3\frac{1}{2}$-in.		
4 line pulleys 5-in. x $2\frac{1}{2}$-in. single belt	4 counterpulleys 10-in. x $2\frac{1}{2}$-in.		
4 line pulleys 5-in. x $2\frac{3}{4}$-in. single belt	4 counterpulleys 10-in. x $2\frac{3}{4}$-in.		
4 line pulleys 5-in. x $4\frac{1}{2}$-in. double belt	4 counterpulleys 10-in. x $4\frac{1}{2}$-in.		
4 line pulleys 6-in. x 2 -in. single belt	4 counterpulleys 12-in. x 2 -in.		
4 line pulleys 5-in. x 3 -in. single belt	4 counterpulleys 10-in. x 3 -in.		
4 line pulleys 8-in. x 2 -in. single belt	4 counterpulleys 16-in. x 2 -in.		
	Net cost		87.57
20-ft. 6 -in. double belt			
240-ft. 2 -in. single belt			
240-ft. $1\frac{1}{2}$-in. single belt			
80-ft. $2\frac{1}{2}$-in. single belt			
80-ft. $2\frac{3}{4}$-in. single belt	Net cost		162.00
72-ft. $1\frac{11}{16}$-in. lineshaft	Net cost		13.10
	Total net cost		\$441.87

ESTIMATE OF SAVING IN KILOWATTS

In the Author's paper, on Lineshaft Efficiency, published in The Journal for December 1909, Par. 32, is given: Kw = 0.0000059 $Lds\mu$

		Plain Bearings	Ball Bearings
L	= total journal load in lb. =	9606	5420
d	= shaft diameter in inches =	$2\frac{7}{16}$-in.	$1\frac{11}{16}$-in.
s	= shaft speed in r.p.m. =	200	600
μ	= coefficient of friction =	0.03	0.0015
Kw	= kilowatt friction loss =	0.90	0.49

Kw., plain = $0.0000059 \times 9606 \times 2\frac{7}{16} \times 200 \times 0.03 = 0.90$

Kw., ball bearing = $0.0000059 \times 5420 \times 1\frac{11}{16} \times 600 \times 0.0015 = 0.49$

Kw. saving = $0.90 - 0.49 = 0.41$

THE HYDROSTATIC CHORD

WITH DISCUSSION OF ITS APPLICATION IN THE DESIGN OF LARGE PIPES OF REINFORCED CONCRETE

By Raymond D. Johnson,[1] Niagara Falls, N. Y.

Non-Member

The hydrostatic chord is allied to the catenary, the parabola and the circle, because all of these curves may be formed by a flexible inextensible substance, supported at its two extremities and properly loaded. If the load is uniformly distributed with respect to a horizontal line joining the supports, the action of gravity will shape the supporting substance to form a parabola. If the load is uniformly distributed with respect to the curve itself a catenary is the result. If the load is applied by fluid pressure, irrespective of the direction of gravity, so that the pressure is of uniform intensity normal to the curve, a circle is formed. If the load is applied by fluid pressure which varies according to the head or depth of water at any point, the curve resulting from this system of forces normal to the curve is a hydrostatic chord, which can easily be imagined as the curve which a flat canvas hammock would take if filled with water.

2 If the canvas were sewed together to form a closed curve, and supported on end as a vertical cylinder, the cross section would become circular under fluid pressure. If now the open ends of the cylinder were sealed with flexible bulkheads and the cylinder was tipped over on its side when completely filled with water the cross section would become a hydrostatic chord, although it would still theoretically be a circle also, until a drop of water was allowed to escape, that is, if the water be regarded as incompressible. Since the shell of the cylinder is assumed inextensible, and a circle encloses the maximum area for a given perimeter, it follows that the mere act of tipping such a cylinder towards the horizontal position would immediately develop infinite stress in the enclosing membrane, if the water could not par-

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tially escape. If one now imagines a hole pricked in the side of the cylinder on top, and connected with a vertical pipe or piezometer, some of the water would escape up into the pipe and at the same time the shape of the cylinder would take on the characteristics of a true hydrostatic chord. The water would continue to rise until the head above the top was just sufficient to hold the remaining water in the equilibrium shape. At this time the surrounding membrane would be in pure tension, equal throughout, and of finite value. The very fact that the tension must be constant in all portions of the shell furnishes an easy means of constructing its shape, because the tension at any point is obviously measured by the product of the radius or curvature and the head at that point.

3 If more water now be poured into the piezometer pipe, the shape of the cylinder will approach a circle; its vertical diameter will lengthen and its horizontal diameter will shorten. It would, however, never become a circle for a finite head of water. Conversely, if water be drawn off, the shape would become more and more oblate until finally the membrane would collapse into a plane surface at zero head.

4 It seems apparent from the above discussion that a circle is not the natural shape for a pressure pipe lying on its side, especially if its diameter is large as compared with the water pressure. No one would think of designing a vertical water tank with an elliptical cross section, and thus subjecting the shell to enormous and unnecessary deforming stresses in its effort to become circular. And yet it has not been unusual, not only to design concrete pressure pipes circular, but even to go to the other extreme and shape the section with its least radius of curvature at the top instead of at the haunches.

5 This latter procedure might be compared to designing a stiff suspension bridge cable, say, for the sake of illustration, of reinforced concrete, and shaping it like an ellipse with its long axis horizontal, instead of the more natural shape in which the radius of curvature would decrease toward the center, instead of increasing. Such a chord is obviously so ridiculous that an example of it could not be found in practice. Instead it would probably be designed of parabolic shape, which would be perhaps as good a compromise as one could reach. If it were really too stiff to adjust its shape to changes of load, as for example when a moving load passed over the bridge, then more or less severe deforming stresses would be the result, but how much less than in the former case.

6 Similarly, although it is impossible to design a stiff pipe of

such a shape that there will be no deforming stresses under the varying conditions of water pressure and back fill and the constant weight of the shell itself, yet these stresses can be reduced to a minimum by adopting a form which lies midway between the ideal equilibrium shapes which the pipe tries to assume under the various water pressures to which it may be subjected. This matter is of much practical importance in large conduits, proper design of the cross section meaning the saving of perhaps one-half the material, concrete or steel.

7 It is not the writer's purpose to take up the mathematics of the hydrostatic chord, nor to follow through the complications of a typical design. The element of judgment enters so largely into such a study that it is impossible to do it justice in restricted space and time. A few general hints may be of service.

8 It is well known that a circular cylindrical shell lying on its side has four nodes, or points of contra-flexure, due to its own weight. These lie at points 50 deg. 36 min. 45 sec., and 146 deg. 19 min. 25 sec., respectively, from the vertical. It can be demonstrated that the locations of the nodes due to the weight of the water within such a cylinder are the same. It can also be shown that the bending moments due to both causes are exactly proportional at all points of the arc, and may therefore easily be combined. The equilibrium shape which would sustain the existing water pressure without any tendency to deform, can easily be plotted from the polar equation of the bending moments in a circle, in terms of the angle of departure from the vertical, remembering that the radial intercept between the circle and the new curve at any point, is a measure of the bending moment at that point, and when multiplied by the corresponding tension at that point of the circle will give the value of the bending moment.

9 Conversely, if the bending moment be divided by the tension, the radial intercept will be the quotient, and may be plotted. The value of this intercept at any angle, and for any assumed head H above the top of the pipe, is as follows:

$$\frac{r\left(\frac{1}{2} - y\right)}{\frac{H + r}{r} - y}$$

where r = radius of the circle, and $y = \frac{1}{4}\cos\phi + \frac{1}{2}\phi\sin\phi$.

10 Any number of such curves may be plotted, according to the number of different values of H assumed, and all of these will of course pass through the same node points.

11 These equilibrium shapes are not identical with the hydrostatic chord, for the reason that the forces acting to produce the latter are strictly normal to the curve itself, whereas in the former case the applied forces are always considered to be normal to the common circle for all the different equilibrium curves.

12 The discrepancy between the two curves for any given head, is, however, so slight as to be negligible for all practical purposes. A measurable difference would scarcely be found except for very low heads, say less than one diameter above the top of the pipe, where the stresses are small and not important. After the head reaches

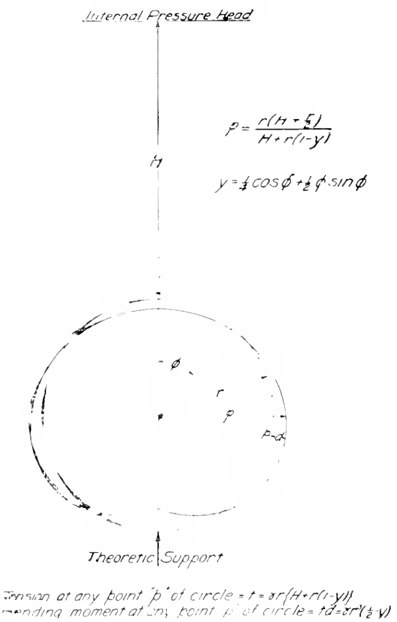

Fig. 1. Equilibrium Curve

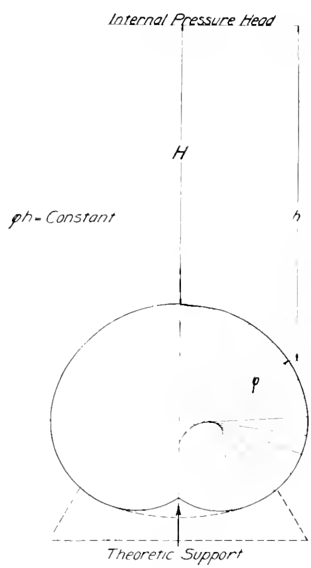

Fig. 2 Hydrostatic Chord for Same Head

a value of five or six diameters above the top of the pipe, the departure from a circular shape is comparatively slight, and therefore this discussion is particularly applicable only to large pipes under low pressure.

13 It will be found that when the pipe is supported on a continuous saddle, as is usually the case, the maximum stress is likely to be located at the top of the pipe, so that if the shell is made homogeneous no other point need be investigated for stress. If the pipe, in-

stead of being circular, is formed on the lines of any one of the equilibrium curves, or better still, on the lines of the true hydrostatic chord for a particular head, then the bending moments induced in it by any other head may be scaled or computated at any point by noting the length of the intercept between such a curve and the curve corresponding to the head under consideration. The value of the tension at any point, which must be multiplied by this intercept, is given by the formula $\alpha r\ [H + r\ (1 - y]$, where α is the weight of a cubic foot of water and the other quantities remain as before.

14 In arriving at the total stress it is necessary to combine algebraically the bending stresses due to weight of shell, back fill and weight of water, and then add to them the tensile stress due to the water pressure. The bending moments in a circle when lying on a flat surface are simply expressed by the equation, $-\alpha\ r^3\ (\frac{1}{2} - y)$.

15 When the pipe rests on a saddle the maximum stress is usually found at the top of the pipe, as before stated; and although its amount is somewhat lessened by the presence of the saddle underneath, it is not considered advisable to rely on this, and it is best to design for stress at this point strictly as though the pipe had a very narrow saddle, or theoretically none at all.

16 The above reasoning is not to be regarded as hard and fast for text-book use, and the conclusions are known to be merely close approximations. Many interesting properties of the hydrostatic chord have been studied by the writer, and much of the mechanics relating to pipe design has been more or less thoroughly worked out; but there is so much of no practical application, and so much time would be needed to coördinate the material, that no attempt has here been made to do so.

17 The curve itself is not new if one considers it the same as the hydrostatic arch with the stresses all reversed, but very little, if any, study of its properties and practical application has been published. Nothing of the kind has ever come to the notice of the writer. As a matter of theoretical mechanics and even of plane geometry there seems to be an opportunity for a little addition to the technical instruction in those branches.

THE SHOCKLESS JARRING MACHINE

In this paper the following subjects have been treated:

THE SHOCKLESS JARRING MACHINE

By Wilfred Lewis, Philadelphia, Pa.

Member of the Society

The title of this paper may appear to the casual reader like a contradiction of terms, but to the foundryman who has hitherto attempted to ram sand by the jarring process, the term "shockless" will be understood to apply only to the foundation or support on which the machine stands.

2 The jarring machine is essentially a sand-packing machine, capable of ramming any mold, large or small, in a minute or less time. By the method employed, the sand is rammed, as it should be, densest at the surface of the pattern and of decreasing density above, thus favoring the escape of gases when the mold is poured. The packing of the sand results from impact between the table on which the mold is carried and the anvil on which it drops. Various means may be used to lift the table and let it drop, but in foundry work compressed air has come to be generally preferred for its convenience as a medium for the transmission of power, and also for the simplicity of the machines resulting from its use. The jarring machine is not universal in its application, nor should it be used without judgment and discrimination. Due regard must be given to the construction of the pattern so as to permit a flow of sand chiefly in one direction, and to withstand successfully the shock of impact in ramming. But, for the broad field of work adapted to its use, there is nothing comparable to the jarring machine as a saver of time and money.

DEVELOPMENT OF MACHINE MOLDING

3 Jarring machines have been in practical use for many years without attracting much attention. The records of the patent office go back to 1869; but like all other types of molding machines, they

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have never been made, until quite recently, for large, heavy work beyond the strength of one or two men to handle. It was quite natural that the molding machine should begin its development in a small way on small work; as the field has widened it has been seen that the possibilities for saving time and money in the foundry have increased with the size of the work adapted to machines.

4 Anyone who has watched a bench molder fill his little flask, ram it in a few seconds with a butt rammer in each hand, then roll it over and draw the pattern with the dexterity of an artist in legerdemain, can appreciate the difficulty of helping him in his work by any mechanical means. Yet the old-fashioned hand squeezer saved some of the ramming time, and the power squeezer saved a little more, but not so much in time as in the strength of the operator, keeping him fresh, with steady hand and eye, for the delicate work of drawing patterns and setting cores. Pattern guides were then devised to assist in drawing patterns, and vibrators were invented to free the pattern from the sand without appreciably enlarging the mold.

5 The use of molding machines on small work has resulted in a substantial saving in the cost of molding, less wear and tear on patterns, and greater uniformity in castings, the saving in weight of the castings due to the use of a vibrator being sometimes an item that soon pays for the installation of the machine.

6 The hand squeezer is, of course, limited in its application to what can be done at one effort by one man, and for larger work power squeezers have generally been employed; but when large molds are squeezed by power, more or less trouble is encountered in the distribution of pressure on the sand. At one time an effort was made to overcome this difficulty by means of a water-bag placed between the sand and the squeezing head. Better results were obtained, however, by judicious tucking in deep pockets, by heaping the sand over deep places, and by scooping it out over high points in the pattern; but the main difficulty in squeezing deep molds lies in the fact that the sand is generally moved against the pattern instead of the pattern against the sand. This results in the greatest density of sand being away from the pattern, next to the squeezing head, and not where it should be, next to the pattern.

7 As shown by Harris Tabor's experiments,[1] presented to this Society in 1892, the friction of sand on the sides of a deep flask may carry a large part of the pressure on the squeezing head. To avoid

[1] Transactions, vol. 13, p. 537.

this difficulty, bottom-ramming machines have been employed, which move the pattern against the sand, but this method contemplates a definite, predetermined movement of the pattern to produce a mold of the density desired, and is subject to variations not easily controlled. Bottom ramming has, therefore, not been adopted to any great extent, and power squeezers have usually been limited in application to flasks not more than two to three feet on a side by a foot deep. Such machines, when designed also for pattern drawing, are comparatively expensive and have marked for a time the limitations of machine molding.

8 During recent years, however, while the power squeezer and the split-pattern machine were completing their development, the much neglected jarring machine has grown steadily in favor and in size, until today there would seem to be no limit to its capacity. These machines are simple in construction and effective in operation, while on large work the saving to be effected by their use probably exceeds that by all other types of molding machines combined. I say on large work, because on small work jarring machines cannot compete with power squeezers of the same capacity, except perhaps in a few special cases where the work is deep.

VALUE OF LABOR-SAVING APPLIANCES

9 The value of any machine depends of course on what it can save, and what it costs to effect that saving; a problem to be worked out in every instance by a systematic time study of all the operations embodied in producing a given result. For instance, if it takes two men eight hours to mold by hand a certain pattern, in a flask 45 in. by 60 in. by 36 in., and if five hours of this time is consumed in ramming sand, a jarring machine would save practically five hours of the time. It would not save any of the pattern-drawing and finishing time, nor any of the time for setting cores, but it would enable two men to make the mold in three hours, instead of in eight hours by hand. Hence, with a suitable jarring machine, two men could put up 2.67 times as much work as by hand.

10 In this case the jarring machine saves more than half of the molding time, and is therefore the most important help in the reduction of cost; but when patterns are rapped with a sledge, and drawn with a crane or hoist, a great deal of the molder's time may be taken up in finishing, or, to put it in more bluntly, in repairing the damage done to the mold by this brutal way of rapping and drawing the pat-

tern. Assuming that about one hour might be spent in finishing each half-mold when made by hand, an effective pattern-drawing machine could easily save two hours; and it is evident that with such a machine two men could make a mold in six hours, thus increasing their rate of molding 1.33 times that by hand. By means of a sand conveyor, or even a clam-shell bucket on a traveling crane, perhaps 30 minutes could be saved, thus enabling two men to make the mold in $7\frac{1}{2}$ hours. With this device only, they could make their rate of molding 1.067 times as fast as by hand.

11 For the purpose of illustrating the effect of coöperation or concentrated effort upon any given piece of work, let us now assume that the demand for the castings above referred to has resulted in the making of three sets of patterns, and that we have three sets of men at work making three molds a day by hand. Now, suppose we give one set of men a jarring machine, another set a pattern-drawing machine, and the third set a sand conveyor. In 8 hours:

The first	set	of	men	will	produce	2.67	molds
" second	"	"	"	"	"	1.33	"
" third	"	"	"	"	"	1.067	"

Six men with three patterns will produce 5.067 molds, instead of three molds by hand, or about 1.7 times as much work.

12 On the other hand, if we have but one pattern and one set of men, and give them the combined help of a jarring machine, a pattern-drawing machine and a sand conveyor, two men will save 5 hours in ramming time, 2 hours in finishing time, and half an hour in shoveling sand, or $7\frac{1}{2}$ hours in all; bringing the time on one mold down from 8 hours to 30 minutes, and increasing the production 16 times. In other words, the same assistance concentrated for the benefit of two men will result in more than three times the production, at less than one-ninth the cost per mold.

13 The above illustration shows, not only the advantage of concentrated effort in the use of labor-saving appliances, but also the wide difference in results that may be realized from the same appliances in different hands. Not only does the concentrated effort in this case save the wages of four men and produce three times as much work, but it also distributes all of the indirect charges, which must ultimately be carried by the product, over a larger output. So much for the savings to be effected.

14 On the other hand, the interest on the investment, the depreciation of the machine and the consumption of power, must be

accounted for; and in addition to all these, the damage that may be caused by the action of the jarring machine upon finished molds, or even upon buildings in the neighborhood, and the annoyance caused by noise and ground waves generally. This damage and annoyance has increased steadily with increase in the size of the machines and in the weight of the loaded table. To meet these serious objections, various expedients have been adopted, among which may be mentioned a reduction in the stroke or drop, and a more or less resilient bedding for the anvil.

PRINCIPLES GOVERNING THE DESIGN OF A JARRING MACHINE

15 These palliatives, however, left much to be desired until the shockless jarring machine, with its anvil rising up to meet the falling table was developed. This has eliminated the chief objection to jarring machines. It is the object of this paper to elucidate the principles upon which it works and to establish its claim to superior efficiency in the consumption of power.

16 In the first place, it must be admitted, that although the packing of sand by the jarring process is very quick and effective in producing results, it is not very efficient under the most favorable conditions, as far as the expenditure of power is concerned, and that under certain conditions the efficiency may be reduced to zero. In the process of ramming, the density of sand is increased 25 or 30 per cent, and if a steam indicator were attached to the cylinder of a power squeezer, it may be questioned whether it would ever show over 1000 ft. lb. per cu. ft. as the work actually done on the sand in squeezing it to proper density. Of course a great deal more power than this would be consumed in the use of water or air as a working fluid, but the work put into the sand would in all probability not exceed 1000 ft. lb. per cu. ft.

17 To produce the same effect by jarring, the sand might be raised to a height of 4 in. and dropped upon an anvil 30 times; but to the weight of the sand must be added the weight of the table and flask, and the excess sand used as an aid in ramming. The first blow struck will cause the greatest flow of sand and will do the most work upon it, while each succeeding blow will increase the density and do less and less work, until, after a certain number of blows, the sand will remain at a density corresponding to the drop. When this point has been reached, the continued action of the jarring machine simply wastes power and produces no effect. The jarring machine is therefore

more efficient during the earlier stages of the process than it can be when the condition of maximum density is approached; and for this reason, the longer the stroke the greater will be the efficiency. Other considerations of a practical nature, affecting the elasticity or durability of flasks and patterns and of the machine itself, necessarily tend to limit the stroke, however, so that in practice it varies from $\frac{3}{8}$ in. on some machines to 4 in. or more on others with an average of perhaps $2\frac{1}{2}$ in.

18 In such machines, the most important consideration is solidity of construction and freedom from vibration of the jarring table. Otherwise the sand will become broken or laminated and the mold will be liable to fall apart in handling. Although lightness of construction in the jarring table is obviously desirable from the standpoint of economy in power, it is certainly not desirable from the standpoint of making perfect molds. The good results which accompany the stronger and stiffer table really cost less and it consumes less power in the end, because there are no failures necessitating repetition, or molds to be thrown away. The importance of solidity in the jarring table will be appreciated after a consideration of the character of rammed sand. It has a certain amount of elasticity, a good deal of resistance to further compression, and some tensile strength, which of course is easily overcome. There must, therefore, be no movement between the pattern, sand and flask, tending to pull the sand apart, and of sufficient amplitude to cause fracture, and no lateral movement tending to slide one layer of sand over another. Such fracture or lamination may be caused by badly fitted pattern boards, flimsy patterns, or crooked flasks not properly bedded, but a light and flimsy jarring table that can be easily warped out of shape will augment the difficulty, and effectually prevent the success of good patterns carefully mounted in strong and firmly bedded flasks.

19 In the molding machine to be described, the table adopted has been formed in one piece with the jarring cylinder, as shown in section in Fig. 2. This table has great depth of beam, and the metal is distributed as it should be for economy of cast iron, in a broad expanse of plate on the tension side, and a smaller mass around the cylinder on the compression side, where the blow is struck. Radial ribs connect the tension and compression sides of the beam, forming a table of enormous strength and stiffness to distribute the central blow of impact equally in all directions. A table of this type is really stiffer than some of the anvils on which other tables are made to drop. At any rate, there is no perceptible vibration of the table when it strikes

its anvil, or rather the buffer ring of leather, or other non-resilient material, interposed to relieve the sharpness of the blow and to reduce the noise. This buffer also helps to reduce vibration and rebound, by reducing the intensity of the force of impact. It is not, however, the rebound of the table from its anvil that injures a mold, so much as the rebound of the flask and sand from the table. Solidity of contact between table, pattern board and flask, is one of the most important elements for the successful working of a jarring machine; yet this detail rarely receives the attention it deserves, and not unfrequently the machine is condemned for this reason, which is no fault of its own.

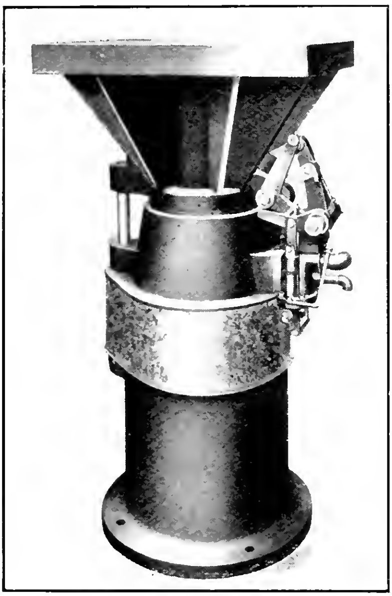

FIG. 1 SHOCKLESS JARRING MACHINE

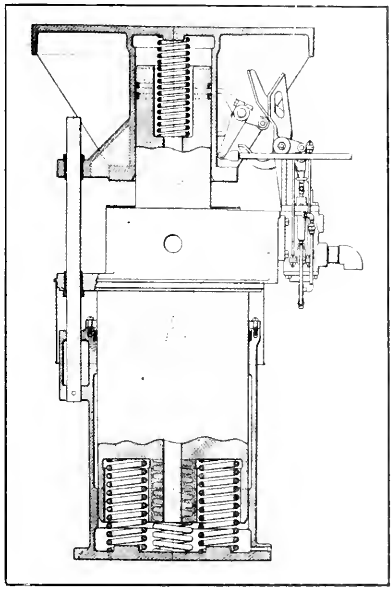

FIG. 2 SECTION OF JARRING MACHINE

20 As already stated, unlimited power may be expended in jarring sand to any given density; and since there is a certain maximum density corresponding to any given drop, it is also quite evident that efficiency increases with the drop, and decreases with the dead weight handled over and above the weight of sand used. But a certain amount of dead weight is inseparable from the process, and for this reason a heavy machine may not be used to its best advantage on light work. Nevertheless, with air as a working fluid the benefit gained by expan-

sion on light work offsets to a great extent the loss from the greater proportion of dead weight carried, giving to the jarring machine which uses air expansively in its cylinder quite a wide range of capacities, under approximately uniform efficiency as far as the consumption of air per cubic foot of sand rammed is concerned.

21 But it is not only the air consumed in lifting the loaded table that may not be utilized to the best advantage. At the instant when the loaded table strikes its anvil, the sudden change in the velocity of the table, whatever that may be, measures the pressure of impact, and the ramming effect is measured by the square of that change in velocity, which is proportional to the energy absorbed, part of which is utilized in ramming sand. Therefore, the greater the change in velocity at the instant of impact the greater the ramming effect, and by the laws of impact, the heavier the anvil the better. Efficiency in a plain jarring machine naturally increases with the weight put into the anvil; but since the cost of the machine depends very largely upon the weight of cast iron or concrete used, the weight of the anvil is generally limited to that of the loaded table. When the anvil is bedded on rock, it becomes practically of infinite weight, and capable of developing the maximum ramming effect for any drop given to the table. A rock bottom does not, however, eliminate the destructive ground waves, and often facilitates their transmission to unusual distances. To mitigate the effect of these shocks, the practice has been to bed the anvil on a timber cribbing, after the manner employed for steam hammers.

EFFICIENCY DEPENDS UPON THE ANVIL

22 So cushioned, the anvil when struck by a loaded table of its own weight will suddenly acquire one-half of the velocity of the table at the instant of impact, after which both table and anvil will be brought to rest by the yielding resistance of the timber cribbing; they will then be returned by its elasticity to their normal position. The loaded table, in this case, loses at the instant of impact only one-half of the velocity it would lose by falling upon an anvil of infinite weight, as exemplified practically in an anvil founded on rock. As a result, the retardation of the table by the compression of the wooden cribbing is less intense and less effective in ramming sand, although this second change in velocity no doubt has some effect, especially in the earlier stages of the ramming process while the sand is comparatively soft. Nevertheless the initial change in velocity, between a loaded

table and a floating anvil of equal weight, is only half as great as the change in velocity of a loaded table falling the same distance upon an anvil of infinite weight; and the ramming effect in the first instance, being measured by the square of the change in velocity, is only one-quarter as much as in the second case, where the whole energy in the falling mass is immediately absorbed.

23 An anvil cushioned upon a wooden crib may be considered as a floating anvil, in which the supporting medium is very dense and highly resistant, but in which also the resistance to compression is trifling compared to that of rock. The stiffness of such an elastic bedding for an anvil might be estimated from the anvil movement, of which no data are at present available; but, however effective it may be in the initial stages of the jarring process, it can have but little, if any, effect upon the final stages after the sand has been rammed to a density in excess of that corresponding to such elastic resistance. It may be said without hesitation, therefore, that anvils cushioned upon wooden cribbing are much less effective than anvils founded in rock, and that such anvils, equal in weight to the loaded table, have in the final stages of the jarring process a comparative efficiency of only 25 per cent.

24 In considering the mechanical efficiency of a jarring machine it is therefore a matter of some importance to provide an anvil of maximum efficiency for any given weight. As a matter of course, the heavier the anvil in any case the better, and the unit standard for all anvils may be one of infinite weight, comparable to a foundation on rock. Such an anvil stands for the highest attainable efficiency, but it is not a practicable construction on account of the destructive ground shocks, which the shockless machine eliminates. We shall presently see how the anvil in this machine compares in efficiency with the usual type of anvil mounted on a wooden crib.

GENERAL DESCRIPTION OF THE SHOCKLESS JARRING MACHINE

25 The shockless jarring machine consists, in its usual form, of a jarring table mounted upon an upstanding plunger forming the anvil, which in turn is mounted in a cylinder base and supported upon long helical steel springs. Compressed air, as the working fluid, is admitted through an automatic valve, under hand control, attached to the plunger or anvil base, and passes first into the jarring cylinder to raise the loaded table. At some predetermined point in the table movement, the air is automatically cut off from the cylinder, and

while the valve is reversing, the confined air will expand and lift the table further from its anvil, provided its initial pressure exceeds the balancing pressure due to the weight carried. Then, when the operating valve completes its reverse movement the air from the jarring cylinder may be exhausted into the atmosphere, but preferably it passes from the jarring cylinder to the anvil cylinder beneath, and the table drops by gravity against the reduced pressure in its cylinder. At the same time, the plunger base or anvil is relieved of a considerable part of the load carried by its supporting springs, which immediately expand, giving the anvil an upward velocity to meet the falling table. When air is expanded from the jarring cylinder into the anvil cylinder this upward velocity of the anvil is augmented and the falling velocity of the table is somewhat retarded, but in any case the momentum of the rising anvil is substantially equal to that of the falling table at the instant of impact. As a result, both table and anvil come to rest with great jarring or ramming effect upon the sand, but without shock or jar upon the foundation or any surrounding material.

26 When the air from the jarring cylinder is discharged at once into the atmosphere the momentum of the falling table may somewhat exceed that of the rising anvil at the instant of impact; but when this air is expanded into the anvil cylinder it compensates more or less for the loss of spring pressure as the anvil rises, and in this case the momentum of the rising anvil may exceed that of the falling table at the instant of impact. The difference, however, need not be very pronounced, and simply results in a slight initial velocity of the table and anvil at the beginning of the next stroke.

27 The advantage of the second expansion is two-fold: it utilizes the potential energy of the compressed air in augmenting the momentum of the anvil, and at the same time it checks the acceleration of the table due to gravity and holds it in contact with the load upon it while falling. Otherwise a poorly fitted pattern board or flask may tend to spring away from its support while falling and cause lost motion, productive of a bad mold. For the same purpose, when the air is discharged directly from the jarring cylinder, a long compression spring between the jarring cylinder and its plunger may be introduced with good effect. In several instances such springs as shown in Fig. 2 have been made to carry half the weight of the table with 8-in. compression. They assist in lifting the loaded table, and retard its acceleration in falling; and by their use the lifting capacity of jarring tables may be considerably augmented. Their chief pur-

pose, however, is to retard the falling table and hold the pattern flask and sand firmly against it in readiness for the coming blow. With such a spring, the action of the table is, of course, somewhat slower in falling and more stroke is required to produce a given velocity of impact. On the other hand, the table rises faster and runs further to produce a given blow, and the increased stroke reduces the percentage of clearance space to plunger displacement. The spring in this position has, therefore, some beneficial effect upon the consumption of power, while serving a much better purpose, in the production of

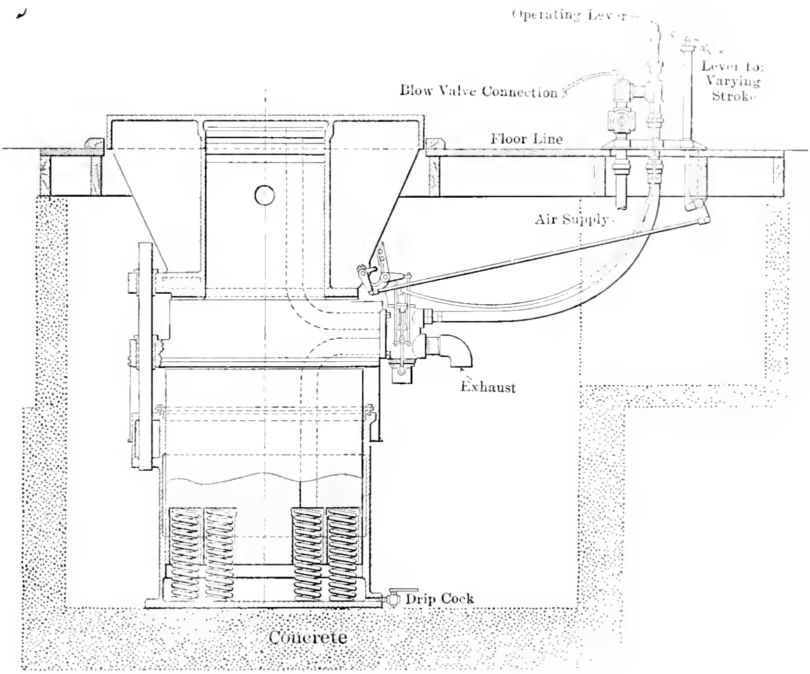

Fig 3. Section of Machine to Handle Molds Weighing 25 Tons

good molds, and although not so important when the air from the jarring cylinder passes through the anvil cylinder, it may be of some value in that case also.

28 The valve mechanism, and the means by which it is controlled, do not particularly concern the present discussion. It will suffice to say that the machine is started and stopped by an operating lever which controls the admission of air to the automatic mechanism. So long as this lever is held down, the machine will run automatic-

ally, and when released, the machine will stop. A latched lever is arranged to adjust the stroke, which can be varied while the machine is running. A safety stop is also provided to limit the table movement through the action of the main valve attached to the plunger base. When pressure is admitted to the jarring cylinder the anvil cylinder opens to exhaust. When in action, it descends while the table is rising and then rises to meet the falling table.

29 Fig. 1 represents the design of a machine now being built for a large foundry to handle half-molds weighing 25 tons. The table is a steel casting 8 ft. x 12 ft., with lifting cylinder 3 ft. in diameter, and the plunger base forming the anvil is a solid iron casting weighing 65,000 lb. This is carried upon 22 steel springs, designed to compress 8 in. under the maximum load and to develop a working stress of only 60 000 lb. per sq. in., which is very much less than the usual working stresses on railway car springs and quite within safe limits. The total weight of the machine complete will probably be in excess of 90,000 lb. This is carried in a concrete pit designed simply to protect the machine and to support the static load on the floor of the pit.

30 The earthquake from a loaded table weighing 65,000 lb., dropping two to three inches upon an anvil bedded in the ground, can readily be imagined. Not only would it undo the work done by the machine, but a large area of valuable floor space in its vicinity would become useless and office buildings at a considerable distance might vibrate in sympathy. In this instance a comparatively small jarring machine of a well-known type, with anvil mounted on wooden cribbing had caused more or less annoyance to the occupants of office buildings in the neighborhood, and the machine above described was designed to avoid any further trouble of the same character.

31 It has been shown that a floating anvil which does not rise to meet the falling table, when equal in weight to the latter, has only one-quarter the efficiency of an anvil founded on rock. The efficiency of such an anvil, when mounted and actuated so as to acquire a momentum equal to that of the falling table at the instant of impact, remains to be determined. Obviously, the anvil will meet the table midway when the latter has fallen half the distance by which they were separated. In terms of the velocity of the table falling the whole distance, its velocity at this point will be $\sqrt{\frac{1}{2}}$, and the velocity of the anvil will be the same. But in this case the velocity of the table is entirely destroyed, while in the previous assumption the change in velocity at the instant of impact was only half the final

velocity. The relative changes in velocity are, therefore as 1 $\frac{1}{2}$ to $\frac{1}{2}$, and the ramming effects in the two cases will be to each other as the square of 1 $\frac{1}{2}$ to the square of $\frac{1}{2}$, or as $\frac{1}{2}$ to $\frac{1}{4}$. Under the assumed conditions the anvil in the shockless machine is therefore twice as efficient as the same anvil cushioned on a wooden crib.

32 It might be shown still further that the vibratory action which develops equal momentum between the table and anvil is more efficient mechanically than any other action which develops unequal momentum. With compressed air as a working fluid, however, it pays to utilize its potential energy in the anvil cylinder rather than throw it away, and a decided gain in effect is realized in this way.

33 It may also be pointed out, that when the sand is soft the change in the velocity of the table at the instant of impact is greater than it is when rammed, because in the first condition the table movement is arrested before that of the sand, while in the latter condition, both stop together.

34 The loss of power in cylinder clearances is well known, and the obvious remedy of a short passage from the valve to the cylinder has led to the use of internal valves of more or less ingenuity and efficiency; but experience in machine design clearly points to the futility of attempting to embody all advantages or completely eliminate all disadvantages in any construction. The best machine for any purpose is the best compromise that can be made between conflicting advantages. Rather than save air by the use of a valve which is comparatively inaccessible, is it not better to sacrifice a little air for the sake of good construction, and accessibility to all working parts? At the same time, it may be said that the air consumed in the clearance passage to the jarring cylinder is not wholly wasted. It adds materially to the work done by expansion in the jarring cylinder, and again, when discharged into the anvil cylinder it adds to the momentum of the anvil. In addition to the consumption of air for any given stroke, it must not be forgotten that the blow struck in the shockless machine is twice as effective as the blow for the same expenditure of power in the usual type of jarring machine.

SPECIAL ADAPTABILITY IN HIGH BUILDINGS

35 Attention should also be called to the possibility of installing a machine of the shockless type on the upper floors of high buildings, where many foundries are now being located. The action of the machine is entirely free from jar except where it is wanted, on the

work produced, and the pulsating variation in floor load while running is no greater than is usually experienced in the operation of power squeezers. A number of these machines are now under construction for installation on upper floors, and in this connection it may be of interest to note that the original experimental machine, shown in Fig. 1, was set up on floor beams over a pit and operated without any vibration appreciable to a man standing on the beams while ramming up a half mold weighing about 1000 lb. In this case the weight of the machine was about 6000 lb., and a stroke of 4 in. was employed. As the movement of the anvil was about 1 in., it met the table when it had fallen about 3 in. The variation in the load in the floor beams was about 10 per cent of the static load carried, or between 600 and 700 lb. This variation, however, was gradual, the anvil rising and falling with the movement of the table. When impact occurred, the load on the floor beams simply ceased to decrease, and began again to increase without transmitting to the floor beams any part of the shock of impact, which was confined exclusively to the jarring table and its plunger base.

DISCUSSION ON LUBRICATION

LUBRICATION AND LUBRICANTS

By Dr. C. F. Mabery,[1] Published in The Journal for February 1910

ABSTRACT OF PAPER

A brief outline is presented of the history of lubrication, with allusion to the sources of the various lubricants. Petroleum products are briefly mentioned as to their composition and properties as lubricants. Graphite is referred to as possessing the most desirable qualities as an unctuous and extremely durable lubricant.

The use of the Carpenter frictional testing machine is explained, in testing light and heavy oils alone and with deflocculated graphite. Results are also presented on the efficiency of deflocculated graphite with water, kerosene and fuel oils as vehicles.

It appears that the coefficient of friction increases with increasing viscosity of lubricant, in close quantitative relations. The addition of 0.35% deflocculated graphite diminishes the friction of every oil and increases its efficiency and durability. Suspended in water, graphite maintains with no variation an extremely low coefficient of friction as do also kerosene and fuel oils.

Every lubricating oil has a well defined limit of load within which it can maintain a continuous film under definite conditions of oil supply and speed.

LABORATORY TESTS OF LUBRICANTS

Discussion by Dr. P. H. Conradson,[2] Franklin, Pa.

Non-Member

To make complete tests of lubricants—oils and greases—requires a great deal of expert knowledge and experience to enable the engineer to interpret correctly the results obtained. This point will be clearer perhaps, if one considers the various classes of machinery to be lubricated under all conditions of service, weather changes, and high and low temperatures.

2 The method of applying the oil to the parts to be lubricated, the condition of the bearing surfaces, composition of the journal and bearings, etc., play an important part int he proper interpretation of

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[2] Chief Chemist, Galena Signal Oil Company.

lubricating oil analysis. An oil that would give satisfaction when applied direct to the journal by means of soaked waste, might fail altogether if the wick method of feeding the oil were used; furthermore, a sight-feed cup with an orifice wide enough might give satisfaction, while a gravity feed through a long pipe of small bore might give very unsatisfactory results.

3 In making a complete investigation of the real or comparative value of a lubricating oil with another oil, we have then to consider the kind of machine to be lubricated, the service requirements and conditions, and the methods of applying the lubricant to the machine, and make our chemical or physical laboratory tests accordingly.

4 Generally speaking, the chemical tests, as made, are very inadequate, as are also the physical tests, especially frictional tests on oil-testing machines, unless the machines are constructed in such a way that the actual conditions can be approximately reproduced. For instance, in testing a spindle oil, the testing machine should be run practically at the same load and speed as the spindles are in actual service. In testing railway car and coach oils, the machine should have approximately the same size journal and bearing as would be found in actual railway car journals. The same is also true as regards speed, load, and the application of the lubricant.

5 While many valuable conclusions may be drawn from properly conducted laboratory tests, those of the greatest practical value come from a close observation of the lubricant in actual service, and we can base our laboratory investigations on the results obtained, especially in comparing different oils intended for the same work. To bring out the point more clearly, let us consider an air compressor, such as is used on street cars and on electric locomotives. As is well known, these compressors are not water-cooled or even air-cooled. It is not difficult to get an oil that will lubricate the compressor cylinder, but it is difficult to find an oil that will not carbonize at the high temperature, often 450 to 460 deg. fahr. in the street-car compressor, and 550 to 560 deg. fahr. in the electric locomotive air compressor.

6 The difficulty lies in the fact that as the compressed air passses through the outlet ports and check valves in the compressor heads, there is a very rapid increase in the temperature. The small amount of oil that goes with the compressed air, if not of the best or suitable quality will then begin to carbonize and cause trouble by forming heavy carbonaceous deposits on the check valves. Now, an ordinary oil-testing machine cannot bring out the essential requirements of a suitable oil for such service, and to make a proper laboratory investi-

gation and test of an air-compressor oil, it would be necessary to have an air compressor and test the oil as near as possible under actual service conditions.

7 Again, we may consider a steam turbine and suitable oils for its lubrication. Ordinary laboratory tests, both chemical and physical, such as are generally used in this country, do not bring out the essential qualities of a suitable turbine oil, because the service requirements and conditions are so entirely different from the general run of machinery, that special tests must be made. Therefore, from a practical point of view, to develop the essential qualities of turbine oils, it is necessary that the service conditions and requirements should be studied first, laboratory tests then being made in accordance therewith as far as practicable.

8 To illustrate, we may consider a steam turbine of the Curtis type, where the oil is forced under high pressure to the step bearing, and then returned to the oil tank. At first this might appear to be a very small matter, but in actual practice and experience it is not, for the following reasons: In the first place, leakage of steam occurs in most of these steam turbines as now constructed; this steam condenses, becomes mixed or churned in with the oil, and if the oil is not of the proper kind, it becomes emulsified. The emulsified oil gradually becomes thicker, and as the same circulating system is used for the rest of the machine, the emulsified oil often causes considerable trouble. Then again, we often find that the amount of oil used in the oil circulating system is entirely too small in quantity, so the oil has to pass through the turbine many times during the hour, in the twenty-four hours, and from week to week. This imposes a severe service requirement on the oil, which gradually becomes polymerized and oxidized, developing petroleum acids. If sulphur compounds are present to any extent, they become gradually oxidized and besides causing corrosion may cause a great deal of trouble from formation of asphaltic and tarry matter, which would clog the filters and orifices through which the oil has to pass. From a practical point of view, therefore, the laboratory tests of turbine oils should be considered along these lines. The same may be said of all lubricating oils intended for use in oil circulating systems, which are now so largely used in stationary power plants, shops and mills, war vessels, steam ships, etc.

9 It is a generally accepted idea that if the oil is adapted to the load and speed, the lower the viscosity, the better lubricant it will be. This, to my mind, holds good only where the service conditions

are uniform, and where the method of applying the oil to the bearing and journal is a positive one, such as in gravity or pressure pump systems. Where the climatic changes are great, as on railroads, this will not hold good.

10 The load and speed of the railroad trains are the same during the summer and winter, and as is well known, the practice in this country is to convey the oil to the journals by means of oil-soaked waste. A satisfactory thin winter oil with a low cold test and low viscosity, containing sufficient lubricating capacity to keep the bearing and journal apart, would not be suitable during the hot season, not because it has not the adequate sustaining power, but because of the method of applying it to the surfaces to be lubricated, making it necessary to use a much thicker oil than is theoretically required.

11 Therefore to make laboratory tests of the relative lubricating values of oils considered from a practical standpoint and to draw correct conclusions from the results obtained, we must consider the kind of machine or machines to be lubricated; the speed and the load; the composition of the bearing metal; whether the journals are iron or hard steel; the method of applying the lubricant, either with wick feed, soaked waste, sight-feed cups, flooded bearing or continuous oil-circulating system; the actual service requirements and the climatic conditions. We must make complete chemical and physical tests as near as possible in accordance with these conditions. I might with propriety state that one oil can not be considered a better lubricant than another oil unless the service conditions and requirements are specified and fully understood and the laboratory tests made in accordance therewith.

12 On the diagrams presented by Professor Mabery the first point of great interest seen is that his tests are run say, for two hours, to get all conditions uniform with a constant and given feed of oil; then the oil supply is shut off without stopping the machine, the tests being continued until the friction and temperature begin to rise rapidly, the time of the break being noted. The length of time from the shutting off of the oil supply to the break would, according to Professor Mabery's theory indicate the comparative lubricating value or endurance of the two oils, other things being equal; that is, if we take two oils intended for the same machinery and same service requirements and conditions, the oil that runs longer on the test machine after the supply is shut off, would be considered the better oil. I think that investigations can be made to great advantage in estimating the comparative lubricating value of two or more oils, by varying

the load and speed to a greater extent than Professor Mabery has done, as well as keeping the temperature of bearing and journal constant during the tests.

13 The second point of interest in Professor Mabery's results is the introduction of a very small amount of pure colloidal graphite in the oil to be tested. Especially interesting are the curves obtained from the mixture of water and graphite.

14 Professor Mabery called attention to the fact that crude oils from different sources as well as different treatment in the refining, produce lubricating oils of great variety, not only as regards the chemical composition and physical qualities, but also in lubricating value. Table 1 is of interest in this connection. Nos. 1, 2, 3, 4 and 5 are the same oil fractionated by means of "Florida Earth." While the flash and fire tests and the gravity remain practically the same, with changes in color and some also in viscosity, the congealing point or cold test has changed materially from the original No. 1, during the successive stages. From a technical and practical standpoint it would indeed be of great value, if Professor Mabery would make frictional machine tests (endurance tests) of these oils, to determine their relative lubricating values.

TABLE 1 LUBRICATING OILS

	1	2	3	4	5	6	7
Flash Point, °F.	365	370	370	370	370	410	415
Burning Point, °F.	440	440	440	440	440	470	480
Gravity, 60°F.	30	30.7	30.5	30.3	30.2	23.0	22.8
Color, °Beaumé.	Very dark	Yellowish	Orange	Red	Deep red	Red	Dark red
Cold Test, °F.	Zero	+18	+25	+25	+25	+5	+20
Viscosity (P.R.R.) pipette @ 125° F.	98	92	94	94	93	85	162
100°	160	149	148	153	151	143	309
90°	205	184	192	195	195	188	410
80°	271	238	249	254	254	253	Drops

15 Nos. 6 and 7 are the same oil before and after being in continuous service in an oil-circulating system about ten months. Here again the flash, fire and gravity tests remain practically the same. The color, as would be expected, has grown somewhat darker, but the congealing point and body or viscosity have greatly changed. The fresh oil had sufficient body or viscosity and gave satisfaction in service at the start, but its durability (endurance) in actual service, as seen from

the rapidly increasing sluggishness or viscosity, is seriously questioned Would Professor Mabery's endurance frictional tests, such as he conducted, have brought out the lack of stability of this oil? This is a practical question that practical men want to know, and to make

TABLE 2 TESTS ON GALENA SUMMER OIL

Bearing metal, brass; journal, steel; bearing surface: length 3.9 in., diameter 3.75 in., width 1.9 in., area 7.4 in.

Number of Test	1	2	3	4	5	6	7	8	9
Pressure on Journal, lbs. total.	1000	2000	3000	3500	4000	5000	5500	6000	6500
Pressure on Journal, lb. per sq. in.	135	270	405	473	540	675	743	810	878
Method of lubrication, flooding bearing.									
Minimum Coefficient of Friction.	.020	.019	.0163	.016	.0156	.0158	.0153	.0152	.0151
Maximum Temperature of Journal, °F.	109	114	115	118	122	134	136	140	144
Temperature of Room, °F.	68	68	68	69	68	70	71	71	71
Elevation Temperature Journal above room	41	46	47	49	54	64	65	69	73
R. p. m. of Journal.	215	220	220	220	223	220	220	220	185
Feet traveled by rubbing surface per. min.	211	216	216	216	219	216	216	216	182

No. of Test	Time	R.p.m.	Temp. Journal °F.	Total Friction Lbs.	Coefficient Friction	No. of Test	Time	R.p.m.	Temp. Journal °F.	Total Friction Lbs.	Coefficient Friction
1	8.40	210	106	20	0.020	6	10.50	220	133	79.1	0.0458
	45	218	107	20	0.020		55	220	134	79.1	0.0158
	50	216	109	20	0.020		11.00	220	134	79.1	0.0158
2	9.00	220	112	38	0.019	7	11.10	220	135	84.0	0.0153
	05	222	114	38	0.019		15	219	136	84.0	0.0153
	10	218	114	38	0.019		20	221	136	84.0	0.0153
3	9.20	220	114	49	0.0163	8	11.30	220	138	92.0	0.0153
	25	220	114	49	0.0163		35	218	140	92.0	0.0153
	30	220	117	49	0.0163		40	221	140	92.0	0.0153
4	9.40	220	117	56	0.016	9	11.50	214	142	104.0	0.0160
	45	220	117	56	0.016		55	180	144	104.0	0.0160
	50	220	118	56	0.016		58	160	145	104.0	0.0160
5	10.00	216	120	63	0.0157	10*					
	05	218	121	63	0.0157						
	10	234	122	63	0.0157						

*Journal stopped at 11.58; pressure 6500 lb.

laboratory tests of real, practical value, problems of this nature must be satisfactorily worked out and answered.

16 In Professor Mabery's endurance tests on the Carpenter machine, only 150 lb. pressure per sq. in. was used on the test journal.

Table 2 gives results of tests of a Galena railway summer oil on the Carpenter oil-testing machine at Cornell University, with increasing loads on the journal from 135 lb. to 878 lb. per sq. in.; also a sort of endurance test to determine the load capacity of the oil.

17 From the results obtained, some interesting curves as to friction and temperatures could be plotted. The main point, however, is to show that with the Galena oil, after the pressure on the journal rises above 400 lb., and up to the maximum load used in the test, the coefficient of friction remains practically stationary, and would give a nearly horizontal curve From a practical standpoint this information is of great value.

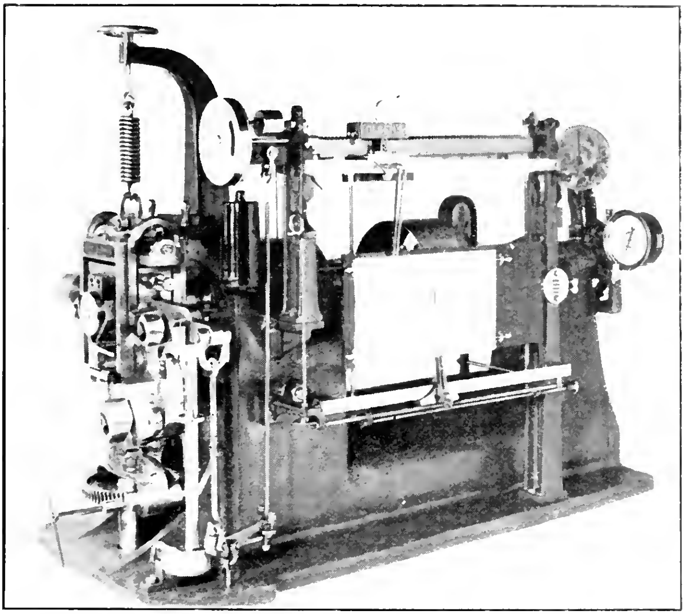


FIG. 1 OIL TESTING MACHINE, 20,000 LB. CAPACITY FOR BEARINGS UP TO 5 IN. BY 9 IN.

18 In connection with the foregoing a few comparative frictional oil tests made on the Galena-Signal Oil Company's oil testing machine will be of interest, because it is the largest and most complete oil-testing machine ever built. Full size M. C. B. car journal boxes and bearings can be inserted. By means of a system of levers, with screw and spring balance, varying loads up to 20,000 lb. can be applied on the test journal, while the machine is running in either direction at

any desired speed up to its maximum. The weight of the load is indicated on a dial; and the friction on the periphery of the journal, in pounds, is recorded on the scale beam in front of the machine. There is also a temperature indicator, a revolution counter and tacho-

TABLE 3 CONSTANT-TEMPERATURE TESTS

Comparative Frictional Tests between Pure Rape-Seed Oil and Winter Galena Railroad Car Oil (Zero Cold Test Oil)

Steel journal, size 5 in. by 9 in. bearing, genuine babbitt; total load on bearing, 10,000 lb.; projected area 15.5 sq. in.; area of contact = 16.40 sq. in.

Pressure per sq. in. projected area..................645 lb.
Manner of lubrication............................ .oil bath
Average friction of four tests for each temperature

Rape-Seed oil			Winter Galena Car Oil		
Temperature Deg. F.	Total Friction Lbs.	Coefficient of Friction	Temperature Deg. F.	Total Friction Lbs.	Coefficient of Friction
300 r.p.m.=392.5 ft. surface speed					
50	21.06	0.00211	50	20.37	0.00205
70	15.375	0.00154	70	14.54	0.00146
90	13.875	0.00139	90	12.75	0.00128
600 r.p.m.=785 ft. surface speed					
56	26.250	0.00263	60	19.94	0.00199
70	25.375	0.00254	70	18.31	0.00183
90	19.75	0.00198	90	15.31	0.00153

Viscosity P. R. R.	Rape-Seed oil	Winter Galena Car Oil
@ 125°F.	80 Units	72 Units
100°	125 "	104 "
90°	141 "	125 "
80°	186 "	160 "
Cold Test	+15°F.	—5°F.

By constant temperature is meant that the oil-bath and bearing is kept at uniform constant temperature during the whole time of test, which lasts not less than one hour after the desired constant temperature of oil and bearing is reached.

meter, and an autographic arrangement showing the friction corresponding to the number of turns of the machine. The test journals and bearings are provided with a device for passing through either water or steam during the tests and there are arrangements for applying the lubricant by any desired method during the tests.

19 In Table 3 we find, first, three series of tests at constant but different temperatures; second, two series of great difference in speed (300 and 600 r. p. m.), all other things being the same; third, compara-

TABLE 4 CONSTANT-TEMPERATURE TESTS

COMPARATIVE FRICTIONAL TESTS BETWEEN WINTER AND SUMMER GALENA RAILROAD CAR OIL

Steel journal 5 in. by 9 in.; bronze bearing: 7800 lb. total load on bearing; 300 lb. pressure per sq. in.; 27.7 sq. in. area of contact; 363 r. p. m. 475 ft. surface speed. Manner of lubrication: oil bath. Average friction of four tests for each temperature.

	Galena Winter Car Oil		Galena Summer Car Oil	
Temperature 65°F.				
Friction, right, lbs.	18.50	18.50	41.00	41.00
Friction, left, lbs.	18.50	18.50	41.50	41.50
Friction, average, lbs.	18.50		41.25	
Coefficient of friction	0.00237		0.00529	
Mean resistance per sq. in. of surface	0.665		1.489	
Temperature 80°F.				
Friction, right, lbs.	15.50	15.00	29.50	28.50
Friction, left, lbs.	15.00	15.00	30.25	29.50
Friction, average, lbs.	15.125		29.44	
Coefficient of friction	0.00196		0.00377	
Mean resistance per sq. in. of surface, lbs.	0.546		1.063	
Temperature 100°F.				
Friction, right, lbs.	11.25	11.00	20.00	20.00
Friction, left, lbs.	10.00	10.00	20.00	20.00
Friction, average, lbs.	10.563		20.063	
Coefficient of friction	0.00135		0.00257	
Mean resistance per sq. in. of surface, lbs.	0.382		0.724	
Flashing Point, deg. F.	315°F.		395°F.	
Burning Point, deg. F.	370°F.		455°F.	
Gravity at 60 deg. F.	27.3°Beaumé		24.3°B.	
Cold Test	+2°F.		+36°F.	
Viscosity (P. R. R.) Pipette, 125°F.	83 Units		189 Units	
100°	124 "		343 "	
90°	156 "		473 "	
80°	201 "		—	

The mean resistance per square inch of surface is obtained by dividing the average total friction by the number of square inches (27.7) area of contact. See Note to Table 3.

tive tests of a purely vegetable oil (rape-seed) with a compounded petroleum oil (Galena lead-oxide process) with viscosities not far apart, as measured with the pipette viscosimeter; fourth, the difference in

friction of the two oils at the slower speed (300 r. p. m.) is very small, while the difference at the greater speed (600 r. p. m.) is considerable, the Galena oil having a much lower friction. This is very instructive when we consider the nature of these two oils, as well as the great load and speed.

20 Table 4 gives an interesting comparison between a winter and summer Galena car oil. Both have sufficient body to carry the heaviest load and speed in railroad service, but owing to the present method

TABLE 5 GALENA CAR, COACH AND ENGINE OILS

SHOWING WIDE RANGE OF VISCOSITY AND COLD TEST

Dudley viscosity pipette, 100 cu. cm. water at 60°F. (15.5°C.) 32 sec.
Redwood viscosimeter, 50 cu. cm. rape-seed oil 60°F. (15 5°C.) 535 sec.

Viscosity taken at 100°F., 37.7°Cel.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Dudley	104	125	140	162	177	195	220	320	276	300	252	348	375	401	426
Redwood	151	183	204	240	260	283	335	378	392	414	480	510	556	595	650

Viscosity taken with Dr. Dudley viscosimeter–100 cu. cm. water at 60°F. (15.5°C.) 32 sec.
Instrument kept in air bath at same temperature as the oils.

Time in Seconds

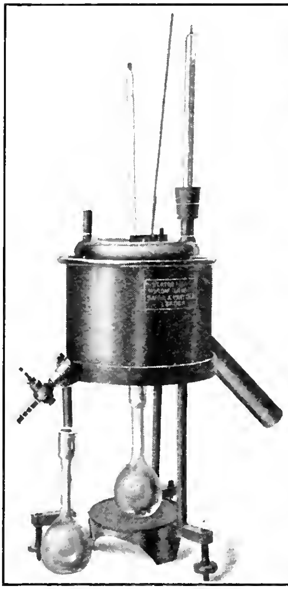
125°F. (51.6°C.)	67	71	86	109	125	138	150	171	197
100° (37.7°C.)	96	99	132	185	214	247	277	318	370
90° (32.2°C.)	115	124	170	243	291	321	362	422	509
80° (26 6°C.)	141	156	216	318	380	439	501		

	Flash Point Open Cup	Burning Point	Gravity at 60°F. Beaumé	Cold Test
SUMMER				
Car	350°–380°F.	425°–450°F.	26.1 to 27.7°	+20° to +40°F.
Engine	350°–380°F.	425°–450°F.	25.4 to 26.4°	+20° to +40°F.
Coach	350°–380°F.	425°–450°F.	24.3 to 24.6°	+20° to +40°F.
WINTER				
Car	210°–300°F.	260°–380°F.	27.4 to 29.0°	–5° to +10°F.
Engine	210°–300°F.	260°–380°F.	26.6 to 27.9°	–5° to +10°F.
Coach	210°–300°F.	260°–380°F.	25.5 to 26.4°	–5° to +10°F.

of conveying oil to the car journals, a thick and sluggish oil with unnecessarily high viscosity is or has to be used during the warm or hot weather, naturally increasing the total train journal resistance, which of course, means excessive coal consumption. Note the great difference in the frictional resistance between these oils. Practical railroaders should ponder a little more on these facts and utilize such knowledge.

21 In connection with preceding tables, Table 5 is of interest. It gives a comparison between two viscosimeters, and illustrates the wide variation in congealing points or cold tests and viscosity possessed by first-class railroad lubricating oils, suitable to all services and climatic conditions. A close study of Tables 5 and 6 will be of great assistance to the practical user of lubricants.

22 I have spoken of the importance of adequate chemical tests in connection with physical and frictional tests. The following tests are therefore useful. While in some cases it is not necessary to subject



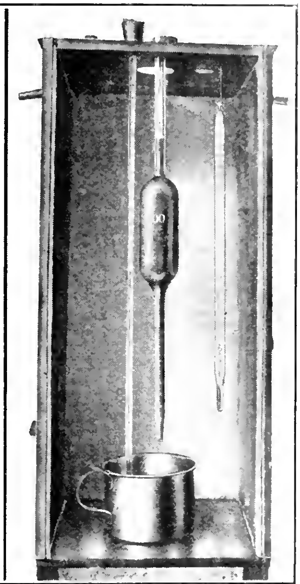


Fig. 2
Redwood Viscosimeter

Fig. 3
Dudley Pipette Viscosimeter

IN USING THE DUDLEY PIPETTE IT IS PLACED IN A CLOSED BOX WITH GLASS DOOR AND THE TEMPERATURE IN THE BOX IS KEPT CONSTANT

the oil to all these tests, they are of great importance in connection with special or unusual service requirements and conditions.

23 *Flash Point and Burning Point.* This test indicates the temperature at which the more volatile elements in the oil begin to vaporize to such an extent as to flash when a small flame is moved over and near the surface of the heated oil. The so-called open-cup method is generally used, and the heat is continued till the oil begins to burn when the test flame is applied. A flash and fire test that is too low

may be objectionable on account of danger from fire, besides causing too large a loss from evaporation under given service conditions. In connection with the viscosity, congealing point or cold test and gravity, the flash and fire test also enables the analyst to form an idea of the source of the petroleum.

24 *Gravity.* The test for gravity is a complementary test which enables the analyst in many cases to form an idea whether the oil is a Pennsylvania, Virginia or Western oil, the last generally having a much higher gravity.

25 *Color.* While not of much importance, other things being equal, an oil with a lighter color or pleasing appearance is oftentimes preferred to a very dark-colored oil.

26 *Odor* at times aids in detecting the kind and quality of fat oils in compounded oils.

27 *Purity* is freedom from water or matters in suspension, whether the oil is clear or turbid, etc.

28 *Gasoline Test.* This test indicates the presence of other foreign matter, or tar and asphaltic matter, if the oil gives a clear solution with 88 deg. gasoline before it is heated to burning point, but gives a precipitate with 88 deg. gasoline after this test. This indicates petroleum compounds which are readily acted upon by heat. Such an oil, in comparison with another oil, other things being equal, would not have the same lubricating value.

29 *Cloud Test* of a lubricating oil is sometimes of value in determining the amount of paraffines present and the behavior of the oil in chilling down to a temperature above congealing point.

30 *Cold Test--Congealing Point--Melting Point.* This test, together with comparative tests of the viscosity of the oil, is of much importance in connection with the service ability of the oil; and should be given careful consideration. The method used in determining the cold test and melting point, as well as getting at the comparative fluidity or sluggishness at temperatures lower than 70 deg. fahr., is not generally considered as it should be. To illustrate:

31 By the so-called P. R. R. method of cold test, valve or cylinder oil is frozen direct in an ice mixture and then stirred by the thermometer till it begins to flow when the bottle is inverted. By this method the oil may show a cold test of say 40 deg. fahr., and if no further observation is taken one has no idea of the fluidity at, say, 60 to 70 deg. fahr.; that is, the cold test would give 40 deg. fahr., but in reality the oil at 60 deg. fahr. would be so sluggish that it would hardly feed through the narrow bore feed pipe to the steam chest and

cylinders, and unless the analyst knows for a fact that the engineer has his pipe covered or warmed in some way, trouble may arise and the oil will be condemned, though it might be of the best quality.

32 Again, if the congealing point is taken by the Standard Oil Co.'s method, that is, the oil with the thermometer inserted in the bottle is put into a cooling box and gradually cooled till the oil just ceases to flow, then the bottle is inverted, or still better, the thermometer stem is lifted from time to time and note is made when the oil "hardly flows" from the stem. Without further observation however, this method,like the P. R. R. method, does not tell all. The rate of cooling or chilling—the time the oil remains in the chilling or cold-test box—plays an important part in proper interpretation of the comparative value of the oil in actual service.

33 *Viscosity.* This test is the bugbear of the oil tester—it may mean so much or so little. Certainly, in my work with the cold test and flash point, one might have a good idea of the quality and adaptability of the oil with the aid of a good viscosimeter.

34 As an adjunct to other tests, by careful study and knowledge of the service requirements, I have found the viscosity tests of the utmost value. In fact from my knowledge of all the analytical data, with the aid of the viscosimeter I can predict quite accurately the comparative friction of two oils under given conditions.

35 *Microscopic Tests.* In testing dark-colored oils, heavy machine oils, and cylinder oils, it is well to put a few drops on a slide and examine under the miscroscope. If carbonaceous matter is held in suspension, or if paraffine crystals are present at ordinary temperatures, by warming the oil a little the paraffine can be made to disappear, and other foreign matters held in suspension are brought out. Other things being equal, an oil that is free or practically so from black carbonaceous specks or flakes is certainly superior to an oil containing these in some quantity.

36 *Saponifiable Fats.* I will not discuss the method to determine these, but will merely point out that two cylinder oils, one containing thirty per cent of fat oil, and the other only 10 to 20 per cent of fat oil, other things being equal, while not of the same intrinsic commercial value, may have an equally good lubricating value. Again, a cylinder oil containing twenty-five to thirty per cent of good fat oil, might give excellent results in a steam engine at 100 to 150 lb. pressure per sq. in., the exhaust steam not being condensed or used over again in the boiler. Yet this oil might be very objectionable in connection with superheated steam and a surface condenser, the reason of course being obvious.

37 *Free Fatty Acids.* Other things being equal, the less free fatty acids are present the better.

38 *Petroleum Acids, Sulphuric Acids, Chemicals.* The presence of pertoleum acids, sulphuric acid, sulphonates and chemicals from imperfectly refined petroleum oils should always be carefully investigated, as the presence of these foreign materials in a lubricating oil, at least for certain services, might lead to serious trouble and complications. A first-class lubrication oil should be free from, or at least contain only traces of these impurities.

39 *Sulphur.* In general very little attention is paid to sulphur and organic sulphur compounds that may be present in lubricating oils. In the future, the sulphur in lubricating oils will have to be reckoned with when these oils are used for turbine service, or where the oil is used over and over again as in an oil-circulating system. Under these conditions the oil, due to the continuous exposure to heat, air, moisture and metal bearings, gradually becomes oxidized and polymerized, forming acid petroleum products, which change it both chemically and physically. The sulphur compounds present in the oil largely augment the corrosive or pitting action on the bearings and journals.

40 In the examination of lubricating oils for sulphur contents, it is important to make a distinction as to how they occur in the oil. I have often found that in making sulphur tests by burning a given amount of oil in lamps to take up the products of combustion in a carbonate of soda solution, it is necessary to consume all the oil in the test lamps, and to make a determination of the sulphur compounds left in the wick. In some poorly chemically refined lubricating oils, the sulphur compounds found in the wick oftentimes amount to from twenty to forty per cent of the total sulphur present.

41 *Maumene Test.* This is the sulphuric acid thermal test, and is of value in connection with tests of compounded lubricating oils.

42 *Evaporating Tests.* By exposing the oils in shallow flat-bottomed dishes in an air bath at 212 to 300 deg. fahr. for six hours, noting the percentage of loss and condition of residue and its behavior when mixed with 88 deg. gasoline, we obtain valuable information as to the amount of volatile matter at low temperatures.

43 *Heat Tests.* For certain service such as air compressors not water-cooled, turbines, etc., valuable data may be obtained by exposing the oils in shallow flat-bottomed dishes in a covered air bath through which air is blown for six hours, at temperatures of 425 to 450 deg. fahr.; studying the residue in the dish by dissolving the same in 88 deg. gasoline, noting whether the gasoline solution is clear or turbid, and the amount of precipitate, if any, on standing.

44 *Emulsifying Tests.* To determine the adaptability of an oil for lubrication in turbines of the Curtis type (step-bearing) it is of the utmost importance to ascertain the behavior of the oil when coming in contact with steam through the step-bearings, whether it forms a thick creamy emulsion or separates readily from the steam and condensed water.

45 *Tabulation of Chemical Tests:*

Flash point
Burning point
Gravity
Color
Odor
Purity
Gasolene tests, before and after flash
Cloud test
Cold test
Viscosity
Microscopic test for carbonaceous matter in suspension
Saponifiable fats
Free fatty acids
Petroleum acids
Sulphuric acid
Chemicals from imperfect refining
Sulphur-lamp test and in wick
Maumene test
Iodine test
Evaporating tests, a given time at 200 to 300 deg. fahr. to study percentage of volatile, and behavior of residues in 88 deg. gasolene tests and acidity.
Heat test, in air bath blowing air over the oil at 425 deg. fahr. and 540 deg. fahr. Examination of residue.
Emulsifying tests, to determine adaptability of the oil, say in turbine service
Tar and coke-forming elements present before and after heat test
Oxidation or gumming tests.
Superheated steam tests
Carbonizing tests in connection with air compressor (not water-cooled) automobile gas-engine lubrication
Capillarity or wick tests.

46 *Frictional tests.* To make frictional tests of oils and greases of practical value requires testing machines constructed for various loads, speeds, sizes of journal and bearings, and methods of applying the lubricant, comparable to those in actual service, as well as devices to keep journal and bearing at any desired constant temperature during the tests.

47 The constant-temperature tests are of importance not only for the purpose of standardizing the machine to get all conditions of bearing, journal and feed, properly regulated before the actual tests begin, but equally so for making comparative frictional tests of two oils of approximately the same viscosity. The two oils may show practically the same friction at a given temperature, but to keep the journal and bearing at this temperature, one may require a great deal more water or steam passing through the journal and bearing; again the friction may be practically the same at a temperature

of say 150 or 125 deg. fahr., but very different at 90 or at 70 deg. fahr. The constant-temperature frictional tests are therefore of great value in conducting comparative tests.

48 As a rule the reports of frictional tests are very incomplete; they should give all the constants and data taken, such as area of contact, projected area, total pressure on journal in pounds, pressure per square inch in pounds, total maximum, minimum and average friction in pounds, coefficient of friction, temperature of journal and bearing, number of revolutions and feet traveled by rubbing surface per minute, duration of tests, constant or freely increasing temperature, amount of lubricant and method of feed, besides complete analytical chemical data.

49 Where the service conditions are uniform or fairly constant, as in mills or power houses, the comparative viscosity and the congealing or fluidity points and friction, other things being equal, would determine the most economical or suitable oil or grease for the service. But in making comparative tests, chemical, physical and frictional, of lubricants under varying service conditions, expecially climatic conditions, it should be borne in mind that two oils showing considerable difference in viscosity, congealing or fluidity, and friction, may be equally good for the service requirements. Manufacturers should submit for comparative tests, samples intended to do service not for the whole year but for the different seasons.

50 In conclusion, what function should a lubricant perform? What are the necessary requisites or qualities that should be inherent in a first-class lubricating oil? These are trite questions, and will be answered briefly:

51 First, the function of a lubricant is to keep the rubbing surfaces (journal and bearing) apart to prevent undue abrasion, friction and heating.

52 Secondly, the necessary requisites or qualities that a first-class lubricating oil should possess in a high degree may be enumerated as follows: Necessary body to withstand the severest pressure in the service for which the oil is intended, so as to keep the rubbing surfaces apart, forming a continuous film between them, filling up the inequalities in the surfaces; the quality of spreading itself rapidly over the rubbing surfaces, with the requisite degree of adhesive power to remain between the rubbing surfaces without creating undue friction and heating; requisite mobility or fluidity at all seasons of the year, and in all climates from the coldest to the hottest, without impairment of the necessary intrinsic lubricating body for the required service;

durability; freedom from mineral and organic impurities, tarry and asphaltic matters; non-drying, non-gumming.

53 Yet no matter how excellent and suitable a material or machine may be, if it is not properly applied or used, the best and most economical results are not obtained. This has brought about the idea of the oil manufacturer's employing practical and experienced men educated in actual service to follow up and watch the proper application and economic use of the various lubricating oils and greases. These men have demonstrated, not only to their employers, but also to the consumer, the practical and economic value of their educational work.

54 The importance of this "following up" is far-reaching. It has gradually brought about a much more systematic and uniform method in lubrication; it has brought about greater economy in the consumption of lubricating oils, and at the same time demonstrated the possibility of better lubrication. In fact, in many instances the consumption of oil has been reduced from 50 to 100 per cent, without impairment of the best and most economic lubrication.

55 From these remarks, you will readily appreciate that to make laboratory tests of lubricants of real practical value, not only to the consumer but also to the manufacturer, involves considerable technical and practical knowledge and experience, besides full and complete laboratory equipment and experience; and the chemist or engineer who is called upon to give a qualified opinion as to the relative, comparative lubricating values of two oils or greases for a given service, considered from a practical and economical service standpoint, has indeed a difficult and oftentimes thankless task to perform.

FURTHER DISCUSSION ON LUBRICATION

William M. Davis.[1] I have not had very much experience with oil-testing machines, preferring to determine the lubricating value of two oils by actual use on the engines or machinery, assuming, of course, that the oil which will keep the bearing cooler is the better lubricant. In my capacity as oil inspector for a corporation in the New England States operating a large number of mills, I found that in some of the mills a heavy engine oil, compounded with about 10 per cent of lard oil, was used on their engines, while the manufacturing department used an excellent grade of straight petroleum machine oil.

[1] Lubrication Engineer, 93 Broad Street, Boston.

2 It occurred to me that the machine oil, which cost about ten cents a gallon less than the engine oil, was quite good enough to use on the engines. One objection to the compounded oil, however, was that it caused gumming in the cups, and sometimes made it difficult to clean the generator and motor coils when gummed on them.

3 In one engine room a thermometer placed in the main bearing of the engine while using the engine oil showed a maximum temperature of 135 deg., the temperature of the room being 80 deg., a rise of temperature due to friction of 55 deg. Readings were taking hourly from the time the engine started in the morning until shutting down at 6 p.m.

4 A bearing under ordinary running conditions will reach a point where the temperature remains constant, the heat radiated equaling the heat generated, as long as the oil feed, the speed and the pressure or load are constant. From the results of the test, Curve A, Fig. 1,

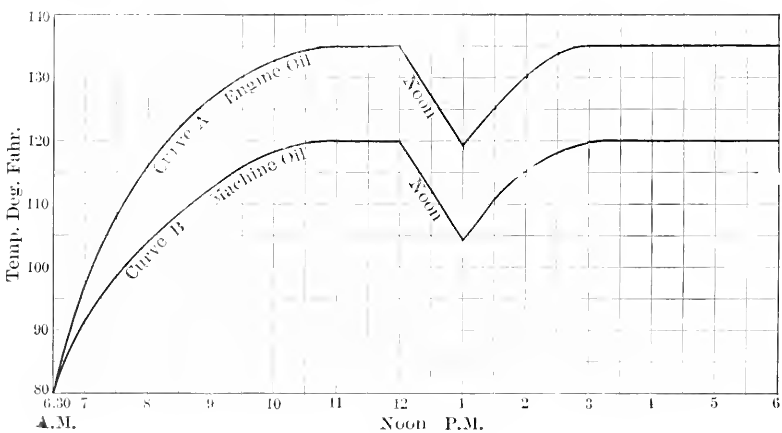


FIG. 1 CURVES PLOTTED FROM TESTS ON OILS

was plotted. As the engine was shut down for forty-five minutes at noon the bearings cooled off a few degrees, but reached the maximum temperature again in an hour or so and remained constant the rest of the day. The temperature of the room remained constant at about 80 deg.

5 The next day the test was repeated, using the machine oil. As will be seen by Curve B, the maximum temperature was only 120 deg., the temperature of the room remaining at 80 deg., showing a rise of temperature due to friction of only 40 deg. This test was repeated on several different engines at different times and the results

were practically the same in each case, proving conclusively that the machine oil was a better lubricant.

6 I do not attribute the higher temperature while using the engine oil wholly to the fact that it contained lard oil, but to the fact that it was considerably higher in viscosity than the machine oil. The viscosity of the engine oil (by Saybolt viscosimeter) was 240 seconds at 100 deg. fahr., and that of the machine oil 178 seconds at 100 deg. I prefer to make the tests in this way, for as Professor Mabery and Dr. Conradson have said, the results of tests on friction-testing machines may not agree with results obtained in actual service.

7 Another test under somewhat similar but more severe conditions showed that the straight petroleum oil kept the bearings cooler than the compounded oil. In this case, however, the oils were of the same viscosity and flash tests. The tests were made on the 22-in. main bearings of a large compound engine making about 120 r.p.m.—a very high speed for a shaft of this size. The engine was fitted with a continuous oiling system, the oil draining back into a chamber under the bearings, no cooling coils being provided to reduce the temperature of the oil. The temperature of the oils flowing on the bearings was 130 deg.

8 On August 25, while using the compounded oil, the maximum temperature of the bearing was 170 deg.—a rise of temperature due to friction of 67 deg., the temperature of the room being 103 deg. The next day while using the straight petroleum oil the maximum temperature was 148 deg., and the following day it was 138 deg., the temperature of the room being 88 deg.,—a rise of temperature due to friction of 54 deg. and 56 deg. respectively. These results showed that the petroleum oil kept the bearings cooler than the compounded oil.

Henry Souther. In the evolution of the automobile business I was called upon to approach the problem of lubricating the automobile engine. The needs are peculiar and absolutely different from those of the steam engine, and very different from those of the large gas engine. I went at the problem in the belief that as high temperatures were to be met, high flash points would be necessary. I very soon discovered that high flash points meant residue oils of high viscosity, and that these oils gummed in the cylinders to such an extent that although they lubricated the engine fairly well while running, the engine very soon refused to run because clogged with tarry matter.

2 A lighter oil was then tried in the cylinders, and a heavy oil in

the crank bearings. These worked well enough until the two oils began to mix. The oil resulting was better than the thick oil formerly used, but still unsatisfactory. I then proceeded to obtain a large variety of oils and try them out. The equipment of my laboratory included a four-cylinder engine running against a dynamo brake; and I had the use of several automobiles. I knew from experience that one of them was easy to lubricate, while another was exceptionally difficult. The engine of the latter was very sensitive, being of very high compression and very close in all its clearances.

3 I soon learned that oils that gave good practical results in an automobile engine possessed certain characteristics; not those obtained with an oil-testing machine, but obtainable with a viscosimeter, with flash and fire tests and with the Westphal balance (specific gravity). But even these tests did not seem to tell the whole story. I had read more or less about certain carbon-residue tests, but rather doubted the efficacy of any such test and the possibility of duplicating any results by destructive distillation of the oil. Nevertheless, I gave instructions to a laboratory assistant, and though he was skeptical at first, he reported in two or three weeks that he thought he could duplicate the results and prove it to me. I checked him by giving him unknown samples and duplicate samples, and he obtained results ranging from 0.1 per cent to 1.5 per cent total residue and checked closely.

4 Thus from these tests I learned what I still consider the desirable characteristics of an automobile–engine lubricant. This is a lubricant which will take care of the main shaft bearings, of the crank-pin bearings and of the piston, and one which when it passes up into the explosion chamber will disappear as much as possible; that is, will leave as little residue as possible. Whether the residue is carbonaceous or not I do not pretend to say; it looks like carbon in a coke-like condition. However, a good oil, as judged by these characteristics, will leave less residue than a bad oil.

5 I measured the viscosity both hot (210 deg. fahr.) and cold (70 deg fahr.). The viscosity when hot, measured by the Saybolt viscosimeter, should be between 40 and 50 seconds. Tested cold (70 deg. fahr.) it should not be over 300 seconds. This latter viscosity limit is placed to exclude the use of residue oils. No distillate oil can be made that will exceed 300 seconds viscosity at 70 deg. fahr., so that my specifications exclude absolutely a residue oil and accept a distillate oil.

6 As to the specific gravity there is some doubt. I am inclined to favor a high Beaumé test—between 28 and 31.

7 In the carbon-residue test I have set an upper limit of 0.5 per cent. In this test the personal equation is admittedly considerable, as is also the fact with many other tests of a practical nature. A number of assistants in my laboratory have been so trained that they can duplicate each other's results without trouble. I believe that other chemists or other testers can duplicate results by following the written instructions for this test, which is more than can be done with some chemical operations.

8 However, tests of the kind referred to in Professor Mabery's diagrams are absolutely valueless in connection with the lubrication of an automobile engine, in which the main crank bearings, the pins and the main journals are flooded with oil.

9 The popular method of lubrication, and I think perhaps the most successful, is the circulating system, which keeps the oil flowing to and from the bearings. The only objection to all systems is that the oil will work into the explosion chamber and leave a coke-like deposit or residue, which when heated to incandescence causes premature ignition. In that case smooth running is impossible. I think that a high compression engine is much more sensitive to this trouble than a low-compression engine. With the former type the temperatures seem to be so much higher that the so-called carbon deposit forms much harder and remains incandescent longer. That may not be true, but it seems to be true from my experience.

Fred R. Low. Some months ago *Power* was asked how much oil was ordinarily used to lubricate the cylinders of steam engines. An appeal to our readers brought out numerous statements concerning individual practice, eighty cases of which, as bearing upon the practical side of this discussion, are here tabulated so as to compare the amounts and costs per horsepower-hour and per million square feet of cylinder surface passed over.

2 A wide variation in these results, affected as they are by the design of the engines, the nature and finish of the surfaces, the quality, pressure and temperature of the steam, the adaptability of the oil to the service, method of application, and above all, degree of care and intelligence exercised in its use, would naturally be looked for, and it is there. If we compare the amounts of oil used per million square feet of surface wiped over by the piston, we find one man using 0.07 of a pint and another 5.94 pints, or 85 times as much, to lubricate the same area.

3 The higher value here mentioned, 5.94 pints, is, however, ex-

ceptional, the next highest value being 2.59 pints, and in the eighty cases analyzed only four go above 2 pints. In the high case the steam was very wet, which indicates that there are advantages to be gained by dry-steaming boilers, steam-pipe coverings and separators, besides the saving of heat units and cylinder heads. The low value, 0.07, is also very far from the average, which is 0.875, only eight of the cases being below 0.25.

4 The monetary importance of this question of cylinder lubrication is indicated by the column of costs per horsepower-hour, the average of which is 0.0075 of a cent. On a 1000-h.p. plant running 3000 hours per year, this would amount to \$225 per year, and on a continuously running plant to between two and three times as much. For the high value, with wet steam, it costs 0.07 of a cent per h.p.-hr., which would be \$2100 per 1000 horsepower, and a 3000-hr. year; while in the lowest case, at 0.00047 of a cent per h.p.-hr. the cost would be \$14.10, a difference which would more than pay the wages of the average engine attendent in this one item alone.

5 It goes without saying that a very small part of the oil ordinarily used would lubricate the surfaces if it could be minutely and specifically applied to the surfaces in moving contact. Water is an effective preventative of such application. Oil will not attach itself to a wetted surface any more than water will adhere to an oily one.

6 The practical men to whom I talk are divided as to the best means of application. Some want the oil atomized, arguing that if it is diffused throughout the steam it will be carried to all the surfaces. Others prefer to keep the oil together and let it trickle down the side of the pipe and be washed along over the surfaces by the flow of steam, arguing that it is the valve and cylinder surfaces and not the exhaust pipe that they want to lubricate. Some prefer to use a force pump with a multiplicity of feeds, leading the oil positively to the various points of application. Some go so far as to drill the seats of Corliss valves longitudinally with several openings to the under surface of the valve; others, admitting the positiveness and efficiency of such systems, claim that they can get their oil where they want it with a simple sight-feed cup in the steam main, with fewer joints to leak, passages to clog and bright work to polish. The idea is prevalent among them that there is apt to be less trouble from a moderately smooth cylinder, one which shows the tool marks, than a highly polished one, the minute rugosities of the less highly finished surface aiding in the retention of the oil. This may have a bearing upon the fact often mentioned, that cylinders that have been run successfully without oil, as

No.	Estimated Horse-power	Description of Engine	Cylinders	Stroke	R. P. M.	Steam Pressure	Sq. Ft. Rubbed over by Piston per Hour	Oil Used: Name or Description	Oil Used: Price per Gal. Cents	Total Amount Used per Hr., Pints	Cost per Hour Cents	Amt. Used per Estimated 1000 h. p. hr. Pints	Cost per Estimated 1000 h. p. Hr., Cents	Amt. per 1,000,000 sq. ft. Rubbed over per Hr., Pints
1	1350	Corliss triple expansion	20–34–52	60	65		1,084,000		28	0.69	2.42	0.511	1.79	0.636
2	675	Cross compound	h.p. 26	48	81		265,800	No. 725 cyl. comp.	75	0.466	4.37	0.69	6.46	1.76
3	675	Cross compound	l.p. 52	48	81		531,600	Capitol oil	35	0.666	2.91	0.99	4.33	1.25
4	975	Cross comp. St. Louis Corliss	22–44	48	85	140	706,500	No. 650 dark valve cyl.	50	0.104	0.65	0.107	0.67	0.147
5	975	Corliss compound	24–44	60	65		694,500		28	0.621	2.17	0.639	2.23	0.89
6	650	Hamilton Corliss cross comp.	20–36	44	100	140	644,400	"600 W"	60	0.21	1.57	0.323	2.42	0.33
7	650	Hamilton Corliss cross comp.	20–36	44	100	140-100 sup.	644,400	Oil of beeswax; 600 fire test Cyl. stock & acidless tallow	90	0.255	2.87	0.392		0.40
8	575	Corliss compound	18–34	48	85		555,900		28	0.465	1.63	0.81	2.84	0.84
9	875	Corliss tandem compound	24–42	48	65	110	539,600	Heavy body comp.	40	0.2	1.00	0.229	1.14	0.37
10	450	Russell cross compound	16–30	24	150		433,300	"600 W"	60	0.25	1.87	0.555	4.16	0.58
11	650	Cross comp. condensing	18–36	42	72		428,100	Improved high pressure cyl.	75	0.111		0.171		0.26
12	290	Cross compound	h.p. 18	36	86	120	146,000	Best grade cyl.	60	0.645	4.34	2.22	15.80	4.42
13	290	Cross compound	l.p. 34	36	86	120	276,000	Best grade cyl.	60	0.323	2.42	1.11	8.32	1.17
14	200	Harris standard cross comp.	h.p. 16	18	200	110	150,800	Harris H. P. valve	60	0.184	1.38	0.92	6.90	1.22
15	200	Harris standard cross compound	l.p. 28	18	200	110	263,900	Rarus		0.131		0.65		0.50
16	400	Cross comp. St. Louis Corliss	14–28	42	85		393,000	No. 650 dark valve	50	0.09	0.56	0.225	1.41	0.23
17	450	Corliss cross comp.	18–30	36	84		380,000	"600 W"	60	0.417	3.13	0.927	6.95	1.10
18	290	Phoenix Iron Works	14–24	18	210	130	376,100		43	0.167	0.90	0.58	3.10	0.44
19	200	Russell tandem compound	13–20½	20	210		368,200	"600 W"	60	0.167	1.25	0.835	6.25	0.45
20	225	Corliss cross compound	h.p. 16	36	84		126,800	Best grade cyl.	60	0.645	4.34	2.86	21.45	5.10
21	225	Corliss cross compound	l.p. 30	36	84		237,500	Best grade cyl.	60	0.323	2.42	1.43	10.72	1.36
22	225	Buckeye tandem comp.	12–21	21	200		363,100	"600 W"	60	0.25	1.87	1.111	8.33	0.69
23	450	Ingersoll cross compound	18–30	24	100		302,000	"600 W"	60	0.167	1.25	0.371	2.78	0.55
24	200	American Ball compound	10½–20½	12	285		277,600			0.273		13.65		0.98
25	180	Westinghouse automatic comp.	11–19	11	300		259,300	No. 725 cyl. comp.	75	0.083	0.78	0.461	4.32	0.32
26	160	Cross comp. Meyer valves	11–18	14	165	115	175,400	Best high grade mineral	50	0.012	0.075	0.075	0.47	0.07
27	160	Tandem comp. piston valve	10½–18	18	115	115	172,100	High grade mineral	50	0.037	0.23	0.231	1.44	0.21
28	70	Ingersoll cross compound	8–12	12	150		94,300	"600 W"	60	0.083	0.62	0.185	8.89	0.88
29	45	Piston valve	30	48	95	150	357,800	"Cyl. oil No. 10"	25	0.417	1.30	0.927	2.90	1.16
30	450	Double eccentric Corliss	30	48	84	150	318,000	"Cyl. oil No. 10"	25	0.5	1.56	1.111	3.47	1.57
31	290	Corliss	24	48	102		308,100			0.091		0.314		0.29
32	290	Harris Corliss	24	48	100		302,000			0.091		0.314		0.30
33	290		24	42	93	120	245,500		60	0.369	2.77	1.272	9.55	1.50
34	200	Greene	20	44	100		230,200			0.91		0.455		0.39
35	160	Sioux Corliss	18	42	105		207,900	"600 W"	60	0.125	0.94	0.781	5.86	0.60
36	290	Harris Corliss	24	48	65		196,200			0.19		0.655		0.97
37	200	Corliss	20	36	102	150	192,200	"Cyl. oil No. 10"	25	0.167	0.52	0.835	2.61	0.87
38	130	New Brown	16	36	125	110	188,800	Harris high-press. valve	60	0.118	0.88	0.908	6.81	0.63
39	250	Atlas single valve automatic	22¼	30	105	110	183,500	Buckeye cyl.	28	0.15	0.525	0.600	2.1	0.82
40	160	Ames	18	16	230		173,700	Capitol oil	35	0.22	0.96	1.375	6.00	1.27
41	160	Corliss	18	36	100		169,800		90	0.1	1.12	0.625	7.04	0.59
42	130	High speed automatic	16	16	250	115	167,800	High grade mineral	50	0.015	0.094	0.115	0.72	0.089
43	130	High speed automatic	16	16	250	115	167,800	High grade mineral	50	0.022	0.14	0.169	1.06	0.13
44	150	Piston valve engine	17½	16	220	80	161,500	Light colored oil		0.03		0.2		0.19
45	130	Slide valve throttling governor	16	30	126	95	158,200	Capitol	35	0.1	0.44	0.769	3.36	0.63
46	120	Single valve auto. Fitchburg	15½	14	275		156,200		28	0.138	0.48	1.15	4.02	0.88
47	160	Atlas four valve	18	15	220	125	155,900	Rarus cyl.		0.094		0.587		0.60
48	130	Harris Corliss	16	36	100	65	150,900	Harris std. grade	60	0.15	1.12	1.153	8.64	0.99
49	130		16	38	92		146,600	Compounded oil	43	0.15	0.81	1.153	6.20	1.02
50	100		14	14	280		143,200	Model cyl.		0.045		0.45		0.31
51	240		22	23	106		140,500	"Eureka cyl."		0.105		0.437		0.75
52	160	Wright Corliss	18	42	70	85	138,800	Capitol	35	0.125	0.55	0.781	3.41	0.90
53	130	Nordberg Corliss	16	36	90		135,800	Valvaline	75	0.2	1.87	1.538	14.38	1.47
54	100	Robt. Armstrong automatic	14	14	260	125	133,500	"600 W"	60	0.15	1.12	1.5	11.22	1.12
55	130	Corliss	16	42	75		132,100		28	0.138	0.48	1.061	3.71	1.04
56	100	Corliss	14	36	100		132,000	"600 W"	60	0.06	0.45	0.6	4.50	0.45
57	200	Slide valve	20	30	80	80	125,800			0.018		0.09		0.14
58	160	Greene	18	30	85		120,200	"600 W"	60	0.03	0.22	0.187	1.46	0.25
59	100	Variable speed, St. Louis Corliss	14	36	90	135–140	118,800	No. 650 dark valve cyl.	50	0.045	0.28	0.45	2.82	0.38
60	85	Atlas automatic	13	18	190	125	116,800	"600 W" vacuum cyl.	60	0.067	0.50	0.788	5.90	0.57
61	110	Ames	15	14	212		116,600	Capitol	35	0.11	0.48	1.0	4.37	0.94
62	100	Automatic piston valve	14	14	223		114,500	High grade heavy	50	0.125	0.78	1.25	7.8	1.09
63	130	Nordberg Corliss	16	32	85	110	113,800	Dark heavy cyl with graph.		0.115		0.885		1.01
64	70	Ideal	12	12	200	100	113,100	Capitol cyl.	35	0.083	0.36	1.186	5.18	0.73
65	70	Buckeye	12	21	165		108,900			0.1		1.428		0.92
66	100	Corliss	14	36	80		105,800			0.049		0.49		0.47
67	70	Atlas single valve automatic	12	18	180	110 very wet	101,800	Buckeye cyl.	28	0.6	2.1	8.57	30.0	5.94
68	70	Corliss	12	36	90		101,800			0.0835		1.19		0.82
69	70	Bates Corliss	12	36	88	100	99,500	Capitol cyl.	35	0.2	0.87	2.857	12.48	2.01
70	70	St. Louis Corliss	12	36	85	135–140	96,350	No. 650 dark valve cyl.	50	0.045	0.28	0.643	4.01	0.47
71	70	New Brown	12	34	90	80	96,200	Franklin oil	75	0.1	0.94	1.428	13.38	1.04
72	50	...	10	14	260	80	95,400	Capitol cyl.	35	0.055	0.24	1.1	4.81	0.58
73	100	Atlas	14	20	130	80	95,400	Capitol cyl.	35	0.2	0.87	2.0	8.74	2.10
74	50	McEwen	10	12	300		94,400	W. P. Miller's cyl. comp.	75	0.04	0.37	0.8	7.50	0.42
75	70	Fitchburg	12	30	100	90	94,400		45	0.055	0.31	0.786	4.42	0.58
76	70	Slide valve	12	14	210	150	92,500	Flake graph. with eng. oil		0.083		1.185		0.90
77	40	Ball	9	12	300		84,750	Pomo oil		0.167		4.175		1.97
78	50	Atlas	10	12	240		75,400		60	0.045	0.34	0.9	6.75	0.60
79	50	Center crank	10	15	170		66,800			0.083		1.66		1.24
80	85		13	17	105	100	60,900	"600 W"	60	0.125	0.94	1.47	11.02	2.05
81	50	Slide-valve	10	12	250	100	31,410	Premium valve oil		0.091		1.82		2.90
		Averages										1.014	6.19	0.97

is common in marine pratice, and which are then lubricated, refuse to run quietly thereafter without oil and plenty of it.

7 There is no doubt that much of the expense of cylinder lubrication and much of the annoyance, interruption of service and cost of repairs due to ineffective cylinder lubrication, can be avoided by a careful selection of the oil for a particular service. It stands to reason that a heavy low-pressure piston and the massive valves of a low-pressure cylinder at a comparatively low temperature, when using the moisture-charged steam from the high-pressure cylinder, will call for a different lubricant than will the lighter but hotter parts of the initial stage.

8 For the lubrication of cylinders using superheated steam and in internal combustion engines an oil of high viscosity and flash point is required. Some of our readers are puzzled to know how such cylinders are lubricated by oils which vaporize at temperatures less than those of the working fluid. The flash points are, however, taken under atmospheric pressure, and it is evident that the oil will remain liquid and sufficiently viscous under the high pressures used, and especially upon the surfaces of the cylinder which do not attain the temperature of the gas or steam, while it would become too limpid to serve as a lubricant or would even vaporize at atmospheric pressure and the temperature of the working fluid.

9 Attempts are made to improve the effectiveness of the lubrication of gas-engine cylinders by timing the injection of the oil. It is to be expected that a given quantity of oil will go further when injected into the piston grooves on the exhaust stroke, where it has that and the succeeding induction stroke to spread over the cylinder walls before ignition, than if injected directly into the cylinder when combustion is going on, in which case it would be only an expensive fuel. The delicacy of such timing may be appreciated when it is recalled that the speed of the piston at the center of the cylinder, where the oil is ordinarily introduced, is about 1200 ft. per min., at which rate it would take a piston one foot in thickness one-twentieth of a second to pass the oil hole, not a long time to get a column of oil into motion and stop it again. I believe sone builders are introducing the oil at the ends of the stroke while the piston is dwelling on the center. It would be interesting if some of the gas-engine men would tell us of present pratice with regard to location of feed, time of injection, and what kind of lubricant gives the best results.

Dr. D. S. Jacobus. At one time at the Stevens Institute of Technology a great many tests were made on lubricating oils. Later on

when anyone sent an oil to be tested we wrote that our experience in making friction tests had convinced us that results obtained in a laboratory gave no indication of the value of an oil as a lubricant in practical service; and further, that if we made friction tests a statement as to their lack of reliability would be incorporated in the report. As a rule those wishing to have friction tests made did not then send oils to us.

2 The above decision was not reached until a great many tests had been made, with various forms of machines. Professor Denton conducted most of these tests, and it was my privilege to be associated with him in the work. In one machine a car axle was mounted on roller bearings and so arranged that the full load that would ordinarily come on the journal could be applied and measured. This machine was run at speeds corresponding to railroad practice, all the conditions of service being copied as closely as possible. The journal was given an end play and a blower was used, to blow air over the entire journal at the speed at which a car would ordinarily travel. Very accurate results were obtained with this machine, which was run for eight or ten hours a day for a number of months.

3 Tests were also made with another machine for determining the friction inside a steam engine cylinder. The frictional force exerted on the piston rings was measured in a way that eliminated the effect of inertia. Before the advent of the above machines we had spent many hours with a Thurston friction oil-testing machine in which the pressure is applied in two directions on the journal at all times, which is not the usual case in practice; and the idea in constructing the special machine was to place the oils under as near service conditions as possible.

4 One feature which was very definitely shown was, that if friction tests are to mean anything at all, the friction of one oil should be compared with the friction of another. The condition of the journal greatly affects the amount of friction, and if a journal is worked down to give the best results, it requires a long time to get it back into shape, should it accidentally become abraided. In fact, as the brasses wear away, the variation in form of the bearing surface will sometimes change the coefficient, and it is no exaggeration to say that with a given oil, results varying by 100 or 200 per cent will be given, by a journal in the same condition as far as the eye can see.

5 In comparing the results with a standard oil, we first determined the friction of the standard oil, then the friction of the oil in question, and then went back to the standard oil. If the two tests with the standard oil agreed substantially with each other we reported the per-

centages of friction, but if they did not agree we continued making experiments, first with one oil and then with the other, until there was an agreement.

6 We made a number of attempts to measure the wearing qualities, or durability, of an oil and finally concluded that there is no such thing as wearing out an oil. Any test of this sort that can be gotten up is simply a measurement of how the oil sticks to the journal and lubricates it.

7 Professor Denton eventually developed the idea of tracing out the lubricating qualities of an oil by observing how it acted in the practical field. One young man connected with the department made a number of trips across the ocean on freight steamers, to determine the quality of one oil as compared with another for marine service. Tests were also made on locomotives and other classes of engines. To me was assigned the task of determining which of two oils would be the best for service on transatlantic liners, by making a trip from New York to Liverpool on the American Line steamer New York, and I can assure you that there is much besides friction to be considered in selecting the oil which will be the best for that sort of work. I do not blame engineers for refusing to try a substitute when they obtain an oil that suits them. There is enough strain in keeping up a maximum speed in an ocean liner without having to worry about the quality of the oil. As far as I know, oil of the composition decided on is still used for the work.

Chas. A. Hague. In lubricating steam cylinders, the condition of the steam makes a difference as to how the oil will hold to the surface. I know of cases in which a very good cylinder oil, recognized for many years, failed entirely to lubricate the valves and cylinders of a large Corliss engine. I think it cost $1.10 a gallon, and after a great deal of experimenting it was found that an oil which cost 30 cents a gallon and was inferior in appearance, lubricated the cylinder perfectly. Apparently the steam was so wet, and the better oil so viscous, that the valves and cylinders did not get any lubrication at all, while the cheaper oil was thinner and more easily distributed.

George A. Orrok. Mr. Souther's remarks concerning brass bearings and babbitted bearings have reminded me of my own experience with bearings, not in automobile engines, but in the larger steam engines. Formerly, it was customary to make the cross-head box and the crank-box of brass, sometimes babbitted, but very rarely.

The boxes were lubricated as well as possible, but they would become hot.

2 We finally discontinued using brass, and I think every large engine builder today uses cast-iron or steel boxes and lines them with babbitt. The trouble from hot bearings has disappeared. I do not think this is due to the use of a larger amount or a better quality of oil, but to the superior construction of the boxes themselves.

PROF. P. E. WALTER.[1] It is well recognized that the usual tests for viscosity, flash temperature and acidity, are valuable for their discriminative testimony, but every engineer is looking for some conclusive test which will give positive information without entailing the expense, time and frequent loss, occasioned by a long-time trial in actual service.

2 One phase of the flash temperature which is easily overlooked, is its relation to the rate of loss by evaporation. Practically all our commercial and lubricating oils are more or less complex mixtures of hydrocarbon compounds, any given oil being made up of compounds vaporizing at different temperatures. The lightest hydrocarbon in the group fixes the flash temperature, and also influences in large measure the evaporation loss. This loss is often a serious consideration, since in continuous oiling systems the gradual thickening and deterioration serve to increase the difficulty of handling the oil, to increase the friction loss in the bearings and cause an actual loss of oil. It seems natural to expect that some relationship should exist between flash temperature and loss by evaporation.

3 With a view to such relationship, the writer carried out in his laboratory a test for evaporation loss under several different temperatures, of three oils whose flash temperatures were carefully determined. While the data thus found are insufficient to establish fully a law of relationship, the results may be expressed with a fair degree of approximation by an equation of the form

$$L = C\left(\frac{t}{100}\right)^3 (400-T)^2$$

where L = loss in per cent of weight in 300 hours.
t = temperature of oil in use.
T = flash temperature.

For oils flashing between 325 deg. and 375 deg. fahr., C may be taken at a value of 0.0003. For oils flashing below 300 deg., C is about

[1] University of Kansas, Lawrence, Kans.

0.00075. These figures apply to oils at temperatures above 100 deg. fahr., to which oil confined in closed crank cases of engines and in some hollow bearings may be subjected for long intervals. The great difference in evaporation loss between oils flashing below 300 deg. and those flashing only 30 or 40 deg. higher, is due to the presence in the former of light hydrocarbon compounds, left there by an inferior method of refining. Such low-flash test oil can of course, be seriously considered only for intermittent service in cool places.

4 The viscosity test is a valuable one, but cannot be taken as a direct measure of the lubricating value of an oil. My own experiments, with several oils all of which are capable of bearing a given load and otherwise performing satisfactorily in service, have shown that the one having the least viscosity will give the lowest coefficient of friction. To the careful practicing engineer who is looking for the best lubricant for his work, and who has found out by the test of actual service that certain oils will operate successfully in his plant, this gives a method of making a final selection.

5 Care must be exercised in following out this method, however, since an oil might be under too great a bearing pressure and still be able to keep the bearing temperature down to a permissible point. Some form of endurance test should be made to yield information on this point. Furthermore, in making the viscosity test, each oil should be tested at several temperatures over a range including that at which the oil is used, remembering that the actual oil film in the bearing is probably several degrees warmer than can possibly be registered by any thermometer set in the metal of the bearing.

6 By plotting curves of viscosity for varying thermometers it is seen that oils with viscosities markedly different at some ordinary temperature such as 60 deg. fahr., may be virtually identical at the temperatures at which they will run in a given bearing, or even reversed in relative values. Tables of viscosity-values of oils at a common temperature are virtually worthless. As a complementary fact it may be noted, that a bearing running moderately warm is not of necessity a cause for condemning one oil in favor of a second. It may simply mean that a condition of temperature equilibrium is reached with the first at a different point from the second, and a consultation of viscosity records at the proper temperatures is necessary before a decision can be intelligently made.

7 It would be both convenient and interesting if data could be obtained by which one could calculate in advance, by some exact method based on a knowledge of the oil, the amount of work lost in

friction of lubricated bearings for different conditions. This would require the determination of the coefficient of friction on special friction machines, and the experience of the writer with three different types leads him to the conclusion that this is impossible. Conditions in practice cannot be duplicated on a special machine; or at most but a limited number of sets of conditions could be so duplicated, and absolute values of the friction coefficient thus obtained are questionable.

8 The friction machine plays an important part in the investigation of a lubricant, however, provided the bearing is always supplied with oil in the same manner. This question of supply is an extremely important one, because a vital factor in the lubricating value of an oil is its ability to spread over the surface. In a special machine, an oil which would not spread well with the system of supply and distribution adopted would give poor results in comparison with some other oil, while under different conditions of supply better results might be obtained.

9 A laboratory investigation must conform to the injunction to vary one thing at a time. The writer is of the opinion that perfect lubrication is necessary in comparing the true lubricating values of different oils, the most reliable method being immersion of the bearing in an oil bath. With a limited supply of oil imperfect lubrication may exist, and the result is neither scientifically exact or of any practical value to a user whose conditions are in any way different from those existing on the machine. There are no laws of imperfectly lubricated surfaces. These considerations bring a cross fire on the man who is striving to reduce both friction and oil bills, making it necessary for him to study the problem of application as well as the oils themselves.

10 In a perfectly lubricated bearing, the resistance to motion is due entirely to fluid friction of the lubricant. This is true whether the motion of the fluid elements be considered as that of one extremely thin layer sliding over and under its adjoining thin layers, below and above, or that of round particles or balls rolling between the bearing and the journal. In either case there is shearing action between the particles, due to the motion. Viscosity is the indication of the magnitude of this shearing force, and hence for perfectly lubricated bearings low viscosity is an index of a good lubricant. But it is plain that to be a good lubricant the oil must first possess the power to form films and maintain those films against pressure, which power is indicated by what is termed "surface tension" of the liquid.

11 The thickness of the film has a double significance, also, since the thicker the film the greater may be the irregularities in the surfaces without an actual puncture; and the thicker film gives a lower rate of motion of one sliding layer of oil over its neighboring layer, if we adopt the sliding theory of lubrication, and consequently a lesser force of resistance.

12 May we not expect then, that the two tests for strength and thickness of oil films would help in the selection of lubricants? Such tests might, in some measure, be applied to greases as well as oils. In the opinion of the writer, the reason why viscosity is not a positive indication of the lubricating value of an oil is simply that it tells but one portion of the story, while the remaining portion must be told by an investigation of oil films. Such an investigation should answer the following questions:

a Do thick films give less friction than thin films?
b Does high surface tension indicate a power to resist high pressures?
c Does high surface tension indicate a power of the oil to spread well and so give perfect lubrication?

Standard apparatus for making the determinations, and a system of numerical relationships, should also be worked out.

MALCOLM MCNAUGHTON.[1] The paper is most interesting, yet lacks one important detail of information, needful if we are to draw any conclusions from the tests. This omission is a test of oils, without graphite, of such character as would indicate their entire suitability to the stated conditions of velocity and pressure. The velocity (115 ft. per min.) and pressure (150 lb. per in.) would indicate the use of an oil of quite high viscosity. The tests did not include any such oils, excepting the cylinder oils, and these were tried at such a temperature that their viscosity was low. Because of this omission we are not able to make any comparison between the best possible lubrication by oil alone, and by oil or water mixed with graphite.

2 The effect of graphite in lubrication may be best considered if we keep in mind that the total friction of a lubricated journal is the sum of the internal friction of the lubricant itself, plus the friction due to the intermittent or continuous contact of the metallic surfaces. It is plain that ordinarily as one increases the other decreases, though

[1] Joseph Dixon Crucible Company

of course we can conceive of cases where a change in lubricant might be followed by an increase or decrease of both components. We may never be able to determine in any particular case what proportion of the total resistance is due to the viscosity of the lubricant and what to metallic contact; nor is this necessary if we know that the use of any particular oil is giving us the best obtainable economy.

3 The addition of graphite, such as was used by Professor Mabery in his tests, to an oil of 154 rated viscosity, even up to 1 per cent by weight, caused no appreciable change in viscosity. A pipette of 100 cubic centimeter capacity allowed the oil, with and without graphite, to flow through in exactly 151 seconds in every trial. Therefore if there is no change in the viscosity of the oil due to graphite, any reduction of total friction must be found in the reduction of the friction between the metallic surfaces. That interposing of graphite between frictional surfaces reduces the friction due to metallic contact is so well known as to need no demonstration.

4 From the preceding statements it naturally follows that where the metallic frictional component is relatively large the graphite effect will be large, and on the other hand where it is small the effect of the graphite will be relatively small.

5 The light oils selected by Professor Mabery for his tests were well suited to show the action of graphite in reducing metallic friction though we are left in the dark as to the effect if oils of suitable viscosity had been used. Keeping in mind what has been said, the lubricating value of a mixture of graphite and water is not remarkable; for as the graphite reduces the metallic friction, the ratio of the fluid friction to the total friction is greatly increased, and the total friction lessened. Many will take exception to the statement that water is "completely devoid of lubricating qualities." It lacks but one quality of the ideal lubricant, and that is ability to keep the metallic surfaces apart. When this defect is provided against by pressure, water gives most perfect results. The matter in Professor Mabery's paper does not give us any basis for forming an opinion as to the relative merits of lubrication by water and graphite, as compared with lubrication by oil alone; to make such a comparison we must know not only their relative efficiency as lubricants but their relative cost, in order to determine their relative economy. If the water plus graphite costs more per gallon than the oil alone, and lubricates no more efficiently, then of course it becomes less economical in use.

6 We may now turn to a consideration of the way in which

graphite serves to reduce journal friction. For purposes of illustration let us consider the case of a fast running journal and a well fitting bearing in which the projection of any irregularity from the normal surface is less than the dimensions of the particle of graphite. The film of oil has its greatest velocity at the surface of the revolving journal and least at the surface of the bearing. Any particle free to move in the oil will be thrown outward and finally come in contact with the surface of the bearing. The journal's motion is always slightly eccentric so that in time every part of the bearing surface has been in contact with the journal. These two forces serve in time to produce on the bearing a veneer of graphite more or less perfect. But in case the irregularities of the frictional surfaces are greater in depth than the dimensions of the graphite particle, it must be seen that the graphite veneer may not be formed at all or be so long delayed in formation as to allow serious trouble to develop. Even approximately perfect bearings are hard to secure and the more they depart from a perfect condition the greater the difficulty in getting the true graphite surface.

7 It is clear that the rougher and more irregular the surface of the bearing the greater the size of the particle should be, in order to prevent the high points from coming in contact with the journal. This fact appears to limit the use of this very finely divided graphite to bearings of the most perfect character and which are the least likely to give trouble. Professor Mabery calls particular attention to the importance of maintaining a high state of perfection in all bearings, which of course is entirely true. But in fact, the normal condition of the average bearing is quite otherwise, and this is the type of bearing which we have most to consider. The statement that the artificial graphite is more unctuous than the natural graphite is denied absolutely. All high grade graphite is unctuous, whether made by nature or artificially.

8 This characteristic is usually determined by rubbing between the finger tips. On trial it will be noticed that while good natural crystalline graphite appears unctuous without pressure, the finely ground artificial graphite must be rubbed with some pressure and brought to a polish before the same effect is secured. The smoothness of this surface does not compare with that of every particle of crystalline graphite, while it is much less resistant to wear.

T. C. Thomsen.[1] Professor Mabery quotes the opinon of well-known experimenters on oil-testing macnines, that "such experiments do not afford results comparable with those in actual practice." This is also the conclusion to which the writer has arrived after having carried out a great number of comparative friction tests on machinery of the most varied description.

2 As Archbutt suggests, it is the quality of "oiliness" or "greasiness" that is so very important when judging the lubricating value of an oil; and this characteristic, viz., the adhesiveness of an oil to different bearing metals, is a factor that can never be or at least has not been up to now, brought under the control of the laboratory. Two oils of practically the same gravity, viscosity, flash point, fire point and color, and both pure mineral, but otherwise made from different crude oils or by different methods, may in actual practice show a difference in friction of as much as 14 per cent. This has been recently proved in Germany, the test being carried out by the electro-technical department of the Bayerische Landesgewerbe-Anstalt in a textile mill.

3 Professor Mabery, while admitting that the conditions on the friction testing machine should be as nearly as possible the same as the conditions under which the oil is actually to be used, has carried out his experiments on a machine which to my mind is as far away as possible from being representative of any bearings at present employed in any kind of machinery. The diameter of the testing machine shaft is 1 in., and the length of the journal about 12 in. In order to keep this bearing and journal in satisfactory operation Professor Mabery found it necessary, not only to mill the journal and bearing to mechanically true surfaces, but by repeated careful milling an even higher degree of permanent evenness had to be maintained. Also, bronze was found unsuitable as a bearing metal and white metal was adopted. (The explanation of this is no doubt that for the abnormal length of the bearing in proportion to the diameter, white metal being more yielding than bronze produced a more uniform bearing pressure.) Further, means were provided for examining the surface of the journal, which means that the oil film was broken, making it difficult for the oil to perform its function, namely that of forming a separating film between the journal and the bearing. If finally the sides of the brasses were not eased away (chamfered), this would form another condition of the bearing which is not, or should not be, met in good engineering practice.

[1] Address, care Wm. F. Parish, Jr., Deutsche Vacuum Oil Company, Kaiser Wilhelmring 4, Cologne, Germany.

4 After Professor Mabery has succeeded in making his most exceptional bearing work satisfactorily, he concludes that the same amount of care should be applied in ordinary factory operations. This suggestion is, to say the least, absurd, as it would increase the cost of all machinery several times and it would not be possible to maintain such a standard of accuracy for any length of time.

5 The net result of Professor Mabery's tests is, that when graphite has been used and the supply of lubricant cut off, it will take a longer time for journal and bearing to "seize" than if no graphite had been employed. This is easy to understand, and has been known ever since graphite was first employed as a "lubricant."

6 Wherever journals or bearings, or say the metal of steam-engine cylinders, are of a porous nature, graphite will fill the pores, acting as a leveller of the surface. If a bearing is cracked and it is desired to continue operation, as otherwise a decrease in the works output might result, graphite can be used to fill the crack, preventing the oil from escaping and thus making it possible to keep the machinery operating the desired length of time.

7 As to the actual friction of bearings in good condition, whether graphite be used or not the friction is practically the same, as shown by Professor Mabery's experiments.

8 Referring to Fig. 2, the coefficients of friction with Nos. 2, 3 and 4 are practically the same. That it is possible to use fuel oil, kerosene and water will be explained by the low bearing pressure and exceedingly good finish of the journal and bearing.

9 It will be understood that a bearing pressure of 70 lb. per sq. in. on this particular bearing, due to its better finish, can be more easily sustained than the same pressure in an ordinary bearing. In other words, if the same mixtures of graphite, fuel oil, kerosene oil or water, were used on ordinary bearings, they might not be able to sustain more than 15 to 20 lb. per sq. in. It will be noticed that Fig. 3 does not contain any curve for water and graphite alone, probably because even with this low pressure it was not possible to operate the bearing without trouble.

10 Referring to Fig. 4, this shows that with an oil consumption of 6 drops per min. it was not possible to maintain an unbroken film. This shows either that the oil must have been of poor quality or that the edges of the bearing were not chamfered, as being sharp they would scrape off the oil film.

11 The differences in the coefficient of friction as shown by the different curves, Nos. 2, 3 and 4, are not greater than might be antici-

pated on any friction machine, and do not prove that the admixture of graphite reduces the coefficient of friction. What the curves do show is that with graphite, after the oil supply has been cut off, it takes a longer time for the friction to increase rapidly than when oil alone is used.

12 As to Figs. 6, 7 and 8, the conditions under which these cylinder oils are used in actual practice, with the steam engine piston moving to and fro over a film of oil mixed with water from the steam, and the oil more or less emulsifying with the water and being heated to a temperature much higher than 210 deg. fahr., are so different from the conditions in the testing machine, that for the purpose of comparing the lubricating qualities of the different oils they have no value. Further the bearing pressure in steam engines between the piston rings and the cylinder walls should always be very slight, nothing like 1200 lb. per sq. in. The temperature of the experiments is stated as 210 deg. fahr., but what is most important to know (from Professor Mabery's point of view) is the actual temperature of the oil film. This I take it, it has not been possible to obtain, and a slight difference in temperature of the oil film would make a very considerable difference in the viscosity of the oils (being cylinder oils), which again would have a considerable influence on the coefficient of friction.

13 Judging from Figs. 7 and 8, it looks as if the trials with the straight oils (600W and Galena cylinder oils) had not been carried out under the same temperature of the oil film as the trials with the oil mixed with graphite. For instance, in Fig. 7, if the straight oil had been a little higher in temperature the coefficient of friction for the first portion of the diagram, up to the point of oil cut-off, would have been lower, and after that point, the oil being warmer, it would be squeezed out of the bearing more quickly, with a resultant sharper rise in the curve for the coefficient of friction, thus getting closer to the curve for the graphite and oil mixture. The same remarks apply to Fig. 8. This suggests that the coefficient of friction, if the temperature of the oil film had been the same in every case, probably would have given the same diagram for the oils used straight as for the oils mixed with graphite.

14 In conclusion, as to the practical question of using oils mixed with graphite, Professor Mabery says that it is possible for graphite in the deflocculated condition to distribute itself readily in water, but that it is quickly precipitated by impurities. As it is not possible for any practical purpose, except perhaps for certain special conditions, to apply a mixture of water and graphite, it will be necessary, in order

to carry out Professor Mabery's suggestion, to use a mixture of oil and graphite, and I presume that also in this case slight impurities would cause the graphite to be precipitated. Therefore if it were used in oil cups or lubricators, without mechanical continuous mixing, the graphite would precipitate and choke the oil channels leading to the bearings. Further, it is the usual practice in many engineering works, to filter large quantities of oil, for re-use, after being used on bearings. It is well known that waste oil mixed with graphite quickly clogs up the filter pads and makes them inefficient, necessitating frequent cleaning and recharging with filter material.

15 As to oil circulating systems, where a certain quantity of oil is continuously circulated through the bearings, returning to a filter and passing an oil pump, and again forced out to the bearings, in such a system also any admixture of graphite would in time mean accumulations of deposit in the lubricating pipes, eventually putting the system out of action if not frequently cleaned out.

THE AUTHOR. The interesting scientific and practical observations accumulated in Dr. Conradson's extended experience in handling lubricants, and here placed on record, will be extremely useful as representing the present state of knowledge on this subject. His results from the testing of oils on the larger machine indicate what I have noted in a great variety of lubricants, that the coefficient of friction very materially diminishes with increasing pressures.

2 Dr. Conradson's tabulated data contain much practical information. Table 1 demonstrates the deterioration from long continued use, that every oil must undergo, by evaporation with consequent changes in congealing point and in viscosity, and lessened durability. His method of testing under constant temperature affords an accurate measurement of the total energy of friction. The total heat absorbed by the water used in cooling may readily be ascertained.

3 As Mr. Davis suggests, temperature tests on factory bearings may give valuable indications as to the comparative efficiency of oils. Why may not some form of friction indicator be set up in any factory for observations on friction?

4 It takes a good oil, as Mr. Souther explains, to stand the hard usage on automobile bearings, especially in crank-case lubrication; decomposition to a greater or less extent is sure, with deterioration in lubricating quality, even to carbonization at increased temperatures.

5 The data of comparative cost of lubrication, tabulated by Mr

Low, illustrate forcibly the great waste that may follow from careless selection of oils, but more especially from lack of attention to the proper use of lubricants.

6 The suggestion by Dr. Jacobus that a standard oil be selected for control of the condition of bearings, seems to be about the only way whereby these conditions may be made dependable for accurate work; in long-continued tests an operator can decide quite accurately from experience, with occasional use of this aid.

7 Mr. Orrok's experience with brass bearings appears to indicate as I have observed on the experimental scale, that babbitt adapts itself more readily to the condition of the journal, especially in heavy work, with less heating and less friction, perhaps by what may be termed metallic flow.

8 As Mr. Walter remarks, continued use of an oil, especially with considerable agitation, as in flooded bearings or in automobile-crank cases, causes evaporation of the constituents, with consequent thickening and gumming, it may be to carbonization with high temperatures. His experience with reference to viscosity coincides with my observations, that economic selection and use of an oil must depend on the intelligence of the engineer for proper appreciation of the data of chemical, physical, and frictional tests, and ability to adapt them to particular conditions. His lucid explanation of the manner in which the film operates, in relation to viscosity and surface tension, should, I think, include the important influence of oiliness. In answer to his question *a*, I would suggest that the thinner the film the less the internal viscosity, and the lower the coefficient of friction. I believe this holds true in a large number of observations, extending through the wide range of oils from kerosene to the heavier cylinder oils and greases.

9 To answer fully the several pertinent questions suggested by Mr. McNaughton would require more space than is available. The speed in these tests is not 115 ft. per min., as he infers, but the 450 revolutions are equivalent to about 400 ft. per min., and the viscosity of the great number of automobile oils examined during the past year is less than 300 sec. Saybolt at 70 deg. The viscosity of the particular oil shown in the chart is 196 sec. Saybolt, at 70 deg. I did not include the data collected on all these oils, as it would have extended the paper to an undesirable length. I may state, however, that every oil examined gave a higher coefficeint alone than when mixed with 0.35 per cent graphite; more than this amount is not desirable, as I explained.

10 I think Mr. McNaughton will find an answer to his question, as to the relative efficiency of water and graphite, as compared with oil, alone, in Fig. 2, which gives the coefficient of an automobile oil alone as nearly 0.02, and that of water and graphite as 0.01; for as mentioned above, in every oil examined graphite diminishes the coefficient.

11 As to the question of comparative cost, I think it is a fact that lubrication by water and graphite is considerably less expensive than lubrication with oils; certainly this is true for automobile lubricants that cost the consumer 50 cents to $1 per gal.

12 Referring to the question of the detailed action and movement of the graphite particles on the journal and bearing, it is a distinguishing quality of deflocculated graphite that it readily forms a continuous coherent film, and serves especially as a surface-evener, by filling up irregularities of the frictional surfaces, so that they approach approximately the condition of perfect bearings. I have recently seen striking examples of this action on journals and bearings run for many months continuously, with lubricants containing the regulation proportion of graphite. A much smaller amount of oil with graphite, and of the oil alone, is required to support the same load and speed after this long-continued use of the graphite. This seems to be an important function of the graphite.

13 I must take issue with Mr. McNaughton as to the comparative specific qualities of deflocculated graphite, which differentiate it from the other forms and adapt it especially for lubrication.

14 Referring to Mr. Thomsen's strictures on the Carpenter machine and my manipulation of it, I would remind him that I suggested the adaptation of a machine to the particular conditions of factory operation. It is not true, as he asserts, that the friction is the same whether oil alone or oil with graphite be used. In every oil I have tried, deflocculated graphite reduces the friction, as is shown on the charts accompanying the paper. The "net results" of my tests are, reduced friction, and longer life of a lubricant carrying deflocculated graphite. This systematic and dependable use of graphite has been known since it has been used in deflocculated form.

15 Figs. 6, 7 and 8 do show plainly that graphite reduces friction in heavy oils at steam temperatures, and that a film of graphite forms and supports the bearing for a long time after the oil is shut off. In Fig. 7 and Fig. 8 the temperatures of the oil films may have been slightly lower than that of the bearing, but not much; at any rate the

temperature of the oil alone, and that of the oil with graphite, were the same.

16 Mr. Thomsen's allusion to my statement that graphite is quickly precipitated from water by impurities leads me to explain that this statement was intended to apply to the deflocculation of the graphite by alkalies and acids, or in general by electrolytes. It does not apply to the ordinary impurities in lubrication either by water and graphite or by oils containing graphite.

17 Mr. Thomsen's statement, that "it is well known that waste oil mixed with graphite quickly clogs up the filter pads and makes them inefficient," shows that he has yet to learn that deflocculated graphite filters readily through any medium. But this use of the mixtures which I have tested, dependent on filtration, is not contemplated in their proper economic application.

CAST-IRON FITTINGS FOR SUPERHEATED STEAM

THREE PAPERS BY PROF. IRA N. HOLLIS, PROF. EDW. F. MILLER AND ARTHUR S. MANN, PUBLISHED IN THE JOURNAL FOR DECEMBER 1909.

ABSTRACT OF PAPERS

The paper by Professor Hollis stated that the examination of cast-iron fittings after long exposure to superheated steam considerably above 500 deg. in temperature has disclosed distortion, cracks and permanent change of shape. Test pieces taken from such fittings have shown irregularity of strength and apparently some reduction. The case has not been conclusively made out by exhaustive tests. The theories as to chemical change rest on doubtful grounds.

Three large cast-iron fittings, two of which had been exposed in service longer than one year, to superheated steam of 578 deg., were burst by hydraulic pressure and found to be amply strong for all purposes, although the test pieces subsequently cut from them failed fully ten per cent below what should have been the tensile strength of air-furnace gun iron out of which they were made. No tests were made of the original metal and nothing conclusive was proved except that the bursting strength of a 14-in. T was 1650 lb. per sq.in.

A calculation of the stresses set up by the expansion of the long line of pipe in which the T's were placed gives a possible stress of nearly 4000 lb., and even more, due to expansion exclusive of the stresses imposed by the steam pressure. It would seem therefore that the deterioration, if any existed, was due to the absence of expansion joints.

The paper by Professor Miller gave the results of tensile tests as specimens of cast iron, gun iron and steel, certain of which were first subjected to the action of superheated steam. While the tests were so few as not to justify many conclusions, it was evident that the metals had suffered a loss in strength due to their exposure to the steam.

The paper by Mr. Mann stated that there is a growing feeling among engineers that nothing but steel will answer as a container for highly superheated steam. A sound high-grade steel casting is practically unaffected by any reasonable superheat and if the user is willing to pay ten cents or twelve cents per pound he need fear no trouble from steel fittings and steel valves. Steel at four cents or five cents per pound has not always proven a success and a reliable material of reasonable price is desirable for a great deal of steam pipe work. A high grade cast iron is capable of withstanding the demands made upon it by superheated steam, and fittings made of this material have been in successful use for the past five years. The paper describes the experience with these fittings.

B. R. T. Collins. Last summer I ran across three valves on pipe lines from boilers on the main steam header so located as to be subjected to excessive expansion strains as described by Professor Hollis. They were 10 in. extra heavy valves, with ribs running between the end flanges and also between the bonnet flange and end flanges. These latter ribs were cracked from 1 in. to 1½ in. deep on all three valves. In addition one valve had a crack 1 in. deep in one of the longitudinal ribs, and in one place on the body showed small criss-cross cracks when examined with the miscroscope.

2 The face-to-face length of this valve was originally 18 in. but after two and one-half years' exposure to a superheat of 150 deg. this had increased to $18\frac{7}{32}$ in. This valve was removed, broken up, and pieces sent to Professor Miller for testing, which showed a tensile strength of 11,300 lb. per sq. in. The iron was very coarse, with crystals something like $\frac{1}{8}$ in. across. This valve evidently was of very poor material to start with, or else it was seriously affected by expansion strains due to its location or to the superheat. Probably all three of these conditions had their share in producing the result obtained.

George A. Orrok. When we first considered the use of superheated steam in our power stations a few years ago there had been developed a type of steam piping which most engineers considered excellent. The piping itself was of steel with VanStone flanges, the flanges being of sufficient thicknesses to prevent buckling. The fittings were all cast iron of a carefully worked out pattern, much stronger than the ordinary high-pressure fittings. The valves were of similar design and the whole piping system was bolted together with steel bolts of larger size and greater number than the ordinary extra heavy standard required.

2 This piping system gave absolutely no trouble with saturated steam. The up-keep of such a system under power station conditions with 200 lb. steam pressure over a period of a number of years was almost nothing; in fact less than $100 was spent on one pipe line in about three years time.

3 Superheated steam, however, introduced another factor, and a very important one. From certain tests made by the General Electric Company it was considered that this superheat might vary over a range of more than 200 deg. and the temperature strains brought upon the piping and the valves would be severe. It was finally determined to make the entire pipe line of steel. The prices on

steel valves and fittings were only a little higher than if of a good quality of cast iron of the thickness required for the high pressure and excessive temperature strains. We adhered to the steel piping with the VanStone joint, but made the VanStone flange of cast steel from the cast iron pattern. The steel fittings were not as heavy as cast iron ones of the same size but differed considerably in the detail. of design. The steel valves followed the design of the fittings and were of various makes, both single and double wedge.

4 Our experience with the steel valves has been good and we feel that they are giving better satisfaction than was to be expected under the circumstances. Troubles developed from blowholes, however, which led to an investigation of the subject about a year and a half ago. We traced most of the blowhole difficulties to improper moulding, improper gating and to over-oxidized metal in the case of Bessemer steel and cold metal in the case of open-hearth steel. The valves and fittings are about equally divided between Bessemer and open-hearth steel, all of the former being made, however, on the baby converter by the Tropenas and Zenzes process. The manufacturers understand better today how to handle the work, and the castings which we are receiving are much better than they were two or three years ago. I believe our troubles with the steam lines resulting from superheat are now practically over, and on one steam main in particular we have done nothing in a year and a half. Whether or not the valves can be shut off absolutely tight I do not know as we have had no reason for doing this during the time.

5 After our first installation of steel fittings and valves I had occasion to look up a number of power stations in which cast iron fittings and valves had been installed for use with superheated steam. In one of these stations I saw fittings which had been under the action of superheat for approximately nine months and had been removed because of the many leaks which had developed. The castings were supposed to have been made from the best air furnace iron, but were swollen and bulged practically all over, the outside being covered with fine hair cracks. None of the castings had gone to pieces but practically all had developed leaks, and were being replaced with steel.

6 At another station a cast iron valve had gone to pieces causing quite a little damage and many other valves and fittings had been seriously affected. There were a number of vertical engines in this station in which superheated steam had been used. All the high-pressure cylinders had cracked in two or three places and they were

replacing the cylinders and had so arranged their pipe line that no more superheated steam could get to them. The fittings which I examined, taken from the superheat line had all undergone a growth in size and the outside was covered with fine hair cracks and seemed very much swollen. Analyses of the metal showed a silicon content of from 1.88 per cent to 2.33 per cent, phosphorus about 0.7 of 1 per cent, low manganese and almost no combined carbon. The tensile strength of the material after its exposure to superheat was in the case of the iron with the silicon content of 1.88 per cent about 4500 lb. per sq. in.; in the case of the silicon content of 2.33 per cent it averaged about 8500 lb. per sq. in. We have no means of knowing what this was when it was first made. Microphotographs of the etched surfaces of this metal show the essentially open character of the iron. In this particular station the superheaters have been removed and their troubles have ceased.

7 In view of the many and excessive strains likely to come on a pipe main with 200 lb. pressure and more or less superheat I have not felt that we are justified in installing cast iron valves and fittings. Even with saturated steam at the above pressure and with the length and size of mains which we are using today in our modern stations it seems to me that the extra expense for steel is justifiable and might probably be saved many times over in the cost of up-keep during the life of the station.

8 A few years ago it was the general impression that superheated steam could not exist in the presence of water. This statement has been made many times and no longer ago than at the Annual Meeting. That this idea is fallacious is, I think, the generally accepted belief today, and we have good evidence that it is possible in a steam pipe carrying steam at 200 lb. pressure and 200 deg. superheat to have a stream of water flowing along the bottom of the pipe. In this case the bottom of the pipe would be at a temperature of possibly 380 deg. fahr., while certain other portions of the pipe in contact with the superheated steam might have a temperature between that of saturated steam and the maximum temperature of superheat.

9 Regarding the difference between European cast iron and American cast iron, it has been my impression that the pig-iron manufacturer here is always trying to make a grade of iron which will command a high price in the market. This iron must be an open iron with reasonably high silicon and almost no combined carbon, the carbon content being in the graphitic state. This iron

will sell readily. If the quality of the iron fell off, and because of a lower silicon content more of the graphite was converted into combined carbon, the iron would become harder—more difficult to machine—and would not command as ready a sale. In Europe, it is my impression that they make much harder iron and are willing to spend the money to machine it. In America we demand an open iron that can be machined easily.

10 If Mr. Mann continues his researches and considers his test specimens in the light of the volumetric composition of the iron; that is, the volume which the compounds of iron and silicon and of iron and carbon occupy in the cast iron, in comparison with the volume occupied by the iron itself, he may find some interesting results.

11 Referring to air-furnace iron, or gun iron as it has been called, I think the great difficulty is the fact that it is almost impossible to control the regular composition of the product. The reverberatory furnace, while a comparatively simple piece of apparatus, is remarkably delicate, and uniform results are obtained only when the very best of care is taken. It is a comparatively easy thing to refine high silicon iron to some kind of refined iron, but it is a much harder thing to get a uniform result from each heat.

W. K. Mitchell. The following notes are taken from several years' personal experience with superheated steam and its effect on cast-iron valves, fittings, etc.

2 Our first intimation that cast-iron fittings and valves gave trouble under superheated steam conditions occurred about three years ago and came in the nature of a surprise, as we had been using superheated steam for some years previous.

3 The first case was in a railway power plant for a high-speed electric line. The plant had been running for several months under a fairly constant load, but owing to a falling off in traffic it was decided to cut down the service to one-half or less, which made the load quite variable. Three months after this had been done the trouble with the fittings and valves began to develop. It was first found that the valves could not be closed tight, and gaskets were giving trouble. Then fittings began to show signs of weakness, cracks appearing on the outer surface.

4 Fortunately these cracks never extended through. In an 8 in. by 6 in. double tee, the metal of which was about $\frac{7}{8}$ in. thick, the cracks did not extend more than half way through, which would

indicate that there is no advantage in very thick castings under such conditions. The most serious of these cracks occurred at the junction of the flange and fittings, and kept growing to so alarming an extent that several fittings were replaced. It was then noticed that the old fittings had lengthened considerably. The original length of some 8 in. by 6 in. double-tee fittings was 35 in., and when taken out and cooled they measured $35\frac{5}{8}$ in. to $35\frac{3}{4}$ in. They had been in service about nine months. Open hearth cast-steel fittings and valves were substituted for those of cast-iron materials and have been working satisfactorily ever since.

5 About the only information we could get bearing on the cause of this growth was from a paper by A. E. Outerbridge, read before the mining and metallurgical section of the Franklin Institute in January 1904. Mr. Outerbridge stated that by repeated heating and cooling of bars he had caused the metal to grow to an almost incredible extent. He exhibited a test bar, the original dimensions of which were 1 in. square cross-section and $14\frac{13}{16}$ in. long, which had been heated some 27 times to a temperature of about 1450 deg. fahr., and cooled again by various methods, some slow and some fast, until at the end of the treatment it had grown to a length of $16\frac{1}{2}$ in. and a cross-section of $1\frac{1}{8}$ in. square. The similarity between the action of the fittings above referred to and the test bars which Mr. Outerbridge exhibited caused us to investigate further along similar lines.

6 The railway plant was designed for a steam pressure of 175 lb. per sq. in. and superheat was intended to be 150 deg. fahr. That this temperature had been greatly exceeded, however, was made evident by the discovery of a board that had been charred by contact with the steam trap which rested on it. This trap was connected to a drip pipe running from one of the elbows next to the strainer on a steam turbine and was about 10 ft. below the elbow. Investigation showed that the trap had been so hot that its legs had burned holes through the board until the trap was not resting on the board at all but was suspended by the pipe.

7 The president of the company that installed the superheaters said that while they were built to give an average of 150 deg. superheat, "the real question was not one of the amount of superheat but of velocity." This seems reasonable when one considers that if the load should fall very low, the velocity of the steam through the superheaters would be considerably reduced and its temperature correspondingly raised. Again, a sudden increase in the demand for steam

would result in a rapid flow through the superheater, and steam at much lower temperature, and these recurring changes of temperature must necessarily cause rapid changes in the lines due to expansion and contraction. We therefore concluded that in this particular plant, at least, the damage to the fittings and valves was not caused by the high temperature itself, but by the constantly changing temperatures due to the change of load.

8 Our contention that the damage was due to variable temperatures seemed to be borne out by the fact that in a cotton mill plant installed three years previously, where the steam requirements for pressure and superheat were higher than those mentioned (the pressure being 200 lb. per sq. in., and superheat 200 to 250 deg. fahr.), the fittings and valves were of regular cast iron, and there had been no trouble to speak of. The load was practically constant, however, varying not more than 15 per cent at any time.

9 On account of the discussion in several publications in the spring of 1908 regarding the disastrous effects of superheat on cast iron, the owners of the mill grew anxious about their piping and asked the writer to look over the system. He found everything normal; the fittings were tight, valves could be operated freely, and in a general way the plant was in good condition. The first installation had been made in 1903, and a second one in 1906, using the same class of fittings and valves.

10 The writer suggested that measurements be taken of all the fittings and valves in the plant and records kept of changes. The original dimensions were determined as closely as possible from the patterns and records of construction, and beginning with July 1908, records were kept of the dimensions of the fittings for a period of nine months. Although the changes in the dimensions were slight, the increase in length of certain of the fittings was such that it was thought unsafe to continue them in use and steel fittings were substituted throughout. Most of the valves, however, are still in service and there have been no failures in either fittings or valves. The following will give an idea of the changes which occurred from the dates of installation to the last date given:—

A 12 in. by 10 in. by 8 in. by 6 in. cross installed in 1903 measured 24. in. in length, and in March 1909 measured $24\frac{21}{64}$ in.

A 10 in. by 8 in. by 8 in. tee increased in the same time from 24 in. to $24\frac{5}{16}$ in. and

A 12 in. by 12 in. by 8 in. by 6 in. cross, 20 in. long when installed in 1903, was $20\frac{3}{64}$ in. long in March 1909.

A 12 in. by 10 in. by 8 in. by 6 in. special cross, 50 in. long when installed in 1906, had grown to $50\frac{1}{2}$ in. in 1909, also

A 10 in. by 8 in. by 8 in. tee, $24\frac{1}{2}$ in. long, measured $24\frac{47}{64}$ in. in March 1909.

11 These facts seem to show that even at high steam temperatures, if cast iron can be kept at a uniform temperature and not cooled off too frequently or too rapidly, it will meet the requirements of superheated steam for a long period; but if the temperature is subject to frequent changes such as occurred in the railway plant, the cast iron will become disintegrated and ultimately fail within a short period of time.

12 In another street railway power house which had been in operation for a number of years with saturated steam at 200 lb. pressure, cast-iron fittings, valves and pipe were used successfully. During 1906 fourteen new boilers were added, making a total of thirty-two. The new boilers were equipped with superheaters intended to superheat to about 50 deg. fahr. New piping was installed similar to the old, with cast-iron fittings and valves, and steel pipe with steel flanges. The fittings were unusually heavy and strong. In the original installation of this piping a white metal gasket had been used, about $\frac{1}{16}$ in. thick, which was very satisfactory for saturated steam. These gaskets had a melting point of about 650 deg. fahr., and no sooner had steam been turned in from the new boilers than the gaskets began to melt, and in the course of a month or six weeks it became necessary to replace every one with material that would stand the temperature of the superheated steam. As the majority of the boilers had no superheaters it was hard to understand how sufficient superheat could be generated by the new boilers to do any harm.

13 Two years later a 16-in. tee in one of the connecting pipes between the main headers was found to be leaking. The leak becoming worse, the covering was taken off and the tee was found to be covered with small cracks or fissures similar to the cracks that had occurred in the fittings taken out of the power house first mentioned, except that a few of the fissures had worked through to the inside. The tee was replaced with a new one of the same material and dimensions. When the defective fitting was examined it proved to be something of a curiosity. Its original dimensions were 31 in. face to face by $15\frac{1}{2}$ in. centre to face. It had grown on one side to $31\frac{7}{8}$ in. and on

the other side to $32\frac{1}{2}$ in. The flanges, which were originally 25 in. in diameter had grown to $25\frac{3}{4}$ in., and as they had been bolted to steel flanges that had not changed under the superheat conditions, they had become dished to a depth of about $\frac{1}{8}$ in. The original thickness of the body of this fitting, as near as could be determined from the pattern, was about $1\frac{3}{4}$ in., but where the surface cracks were most numerous careful measuring gave a thickness of almost $2\frac{1}{4}$ in. Of course, there is always the possibility of the core moving when a casting is being made, but the thickness of this fitting was quite uniform throughout.

14 In this plant, the trouble did not stop with the fitting. Several valves began to show cracks and were replaced. Then the high-pressure cylinders of the engines became affected, and several had to be renewed. The engineers finally decided to take out the superheaters, and the plant is now running without superheat. This is a typical street railway plant, subject to changes of temperature similar to the one first mentioned. Fig. 1 shows the original dimensions of the 16-in. tee and its dimensions after coming out of the line.

15 It is of interest to note that at the same time these superheat boilers were installed in the railway plant, similar boilers with engines, piping, valves and fittings of the same type and material, were installed in a lighting plant in the same city, where practically no trouble of any kind had developed. This seems to indicate that a much more constant load is maintained.

16 It is my opinion that in plants where the load is constant and the temperature of the steam therefore constant, properly designed piping with cast-iron fittings of good material will do the work satisfactorily and be safe for a long time. I believe there is no advantage in using cast-iron alloys known as semi-steel, ferro-steel or gun iron. In the railway plant first referred to, the fittings were of cast iron from one foundry; gate valves of semi-steel from another; and stop, check and emergency stop valves also of semi-steel from a third. The results in each case were practically the same. A specimen from an 8 in. by 6 in. double tee which had been in service about nine months gave a tensile strength of 13,750 lb. per sq. in. The chemical analysis of this piece gave the following: Carbon, 2.502; Phosphorus, 0.461; Sulphur, 0.083; Silicon, 2.435.

17 Two test pieces from the 16-in. tee showed tensile strengths of 4970 lb. and 4340 lb. Chemical analysis: Silicon, 2.33; Sulphur, 0.07; Phosphorus, 0.68; Manganese, 0.39; Total Carbon, 3.18.

18 In Fig. 1 is shown the first fitting listed in Par. 10, taken from

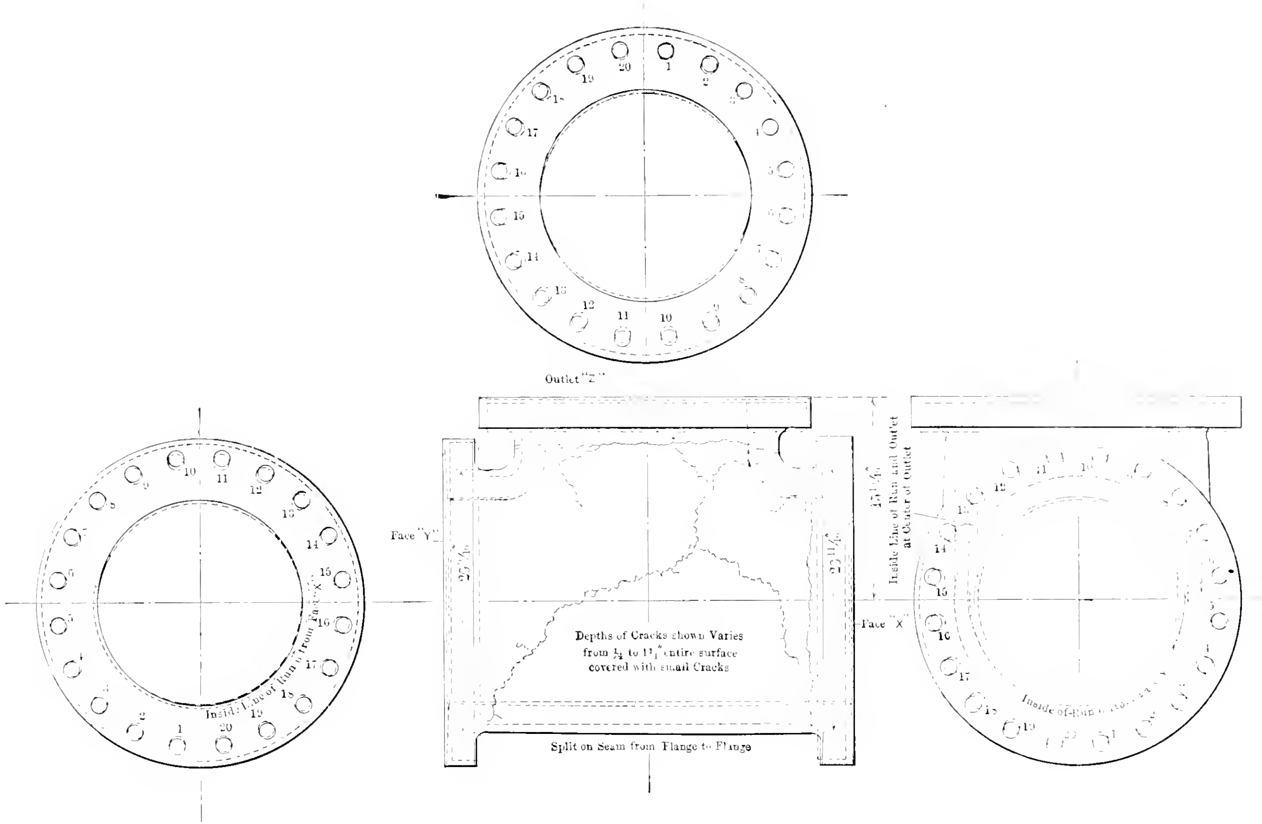


FIG. 1 CHANGES IN DIMENSIONS OF 16-IN. TEE REMOVED FROM STREET RAILWAY POWER STATION

the cotton mill plant where it had been in use several years under superheated steam, the temperature of which, however, was nearly constant. This fitting was tested under hydraulic pressure. At first the pressure was put up to 1100 lb. per sq. in., when the gaskets leaked and the pressure had to be reduced to zero in order to tighten up the gaskets. The fitting was then tested again and broke at a pressure of 1250 lb. There were no serious defects in the fitting. One small surface crack was of so little moment as not to

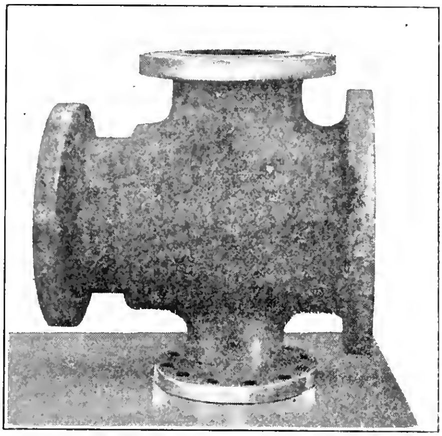


FIG. 2 12 IN. BY 10 IN. BY 8 IN. BY 6 IN. EXTRA-HEAVY CAST IRON FITTING IN USE WITH SUPERHEATED STEAM, 1903-1908

require special attention. A testpiece from the fitting showed a tensile strength of 15,900 lb. per sq. in. The chemical analysis was as follows:

Total carbon	3.05
Phosphorus	0.769
Sulphur	0.06
Silicon	2.07

19 It will be noted that the silicon in this specimen is lower than in the two castings just mentioned and I think this had a good deal to do with the case, as well as the fact that the load and temperature were constant.

20 While open-hearth steel castings seem to be successfully used under superheated steam conditions, I do not believe they will last indefinitely because of their extreme thickness. There must be

changes taking place similar to those in cast-iron, due to temperature changes, but the ductility of open-hearth steel will undoubtedly delay the process of disintegration for a longer period. The material which we recommend and use today for high-pressure superheated steam, is wrought steel throughout, with welded nozzles instead of fittings, and steel flanges, using bends in all cases in preference to short elbows.

John Primrose. During the past eight years the writer has been in close touch with many plants, containing upwards of fifteen hundred installations using superheated steam, and in a position where troubles would be promptly reported to him. Almost without exception these plants use cast-iron fittings in their pipe connections. The fact that no one of these plants has reported troubles with its fittings is in striking contrast to the comparatively few instances where superheated steam has been charged with being the cause of trouble with cast-iron fittings. In order that there should be no doubt about the absence of trouble due to superheat, letters were written to ten concerns known to have been passing superheated steam through cast-iron fittings for the past eight years, at from 100 to 150 deg. superheat, asking the following questions:

Question One. Are not the tees, elbows and valves of cast-iron in the branch and main steam lines leading from the boilers? Seven answered yes, two replied that some fittings and valves were of cast-iron and some of cast-steel, and one replied that while the fittings were originally of cast-iron some tees had been changed to cast-steel, but stating positively that the change was not made because of any ill effects of superheated steam.

Question Two. Are fittings of extra heavy or standard weight? Nine replied that they used extra heavy fittings, and one standard weight.

Question Three. What steam pressure do you ordinarily carry? One used steam pressure of 100 lb., six used 150 lb., one 165 lb., one 185 lb. and one 200 lb.

Question Four. Have you ever noticed any injurious effect of the superheated steam on valves or fittings? Eight answered no, one that no trouble was experienced in fittings, but that valves with cast-iron bodies and brass seats were difficult to keep tight, and one reported no trouble further than the baking of a hard deposit on inside.

Question Five. Have you ever found it necessary to replace

any of these valves or fittings with cast-steel? Eight answered that no fittings or valves had been replaced on account of superheated steam. One answered that they had replaced no fittings, but some globe valves, and one answered that they were replacing some fittings with cast-steel, but upon further inquiry it was found that this was not because of the ill effects of superheat, but because the steam mains were being changed to contain VanStone joints and they wished to change the fittings to standard length and deemed it advisable to use cast-steel.

Question Six. Of what material are the gaskets in the steam line? Seven use corrugated copper or bronze, two sheet packing, and one asbestos.

2 The chief engineer in charge of a plant in the middle west, of some 20,000 h.p., writes that nothing has developed in any of the cast-iron fittings to show that they are in any way affected by the use of superheated steam. This plant has been in operation about five years.

3 Such evidence as the foregoing proves pretty conclusively that superheated steam does not have an injurious effect on cast-iron. There seems to be no very good reason why it should. There is nothing extraordinary in the fact that several cast-iron fittings have failed when passing superheated steam. The failures were probably due to inferior metal, or to strains developed by expansion or contraction of the pipe lines, as suggested by Professor Hollis and Mr. Mann. These are much more plausible theories than that superheated steam at a temperature of 500 deg. to 600 deg. fahr. has any effect on the metal. In investigations by Mr. Outerbridge and Professors Rugan and Carpenter on the growth of cast-iron when repeatedly heated, their experiments were started at 900 deg. C. or 1652 deg. fahr. Such instances as the growth of grate bars, etc., are all at temperatures far exceeding anything used in superheated steam work for power plants.

4 Samples of cast-iron taken from fittings passing superheated steam for years have been polished and micro-photographed before and after etching, and compared with samples treated in the same way, taken from fittings passing saturated steam. The report states that there is no evidence of a change in the carbon conditions, or of exposure to superheated steam, and in support of this a well known foundryman gives his opinion that a temperature below 900 deg. fahr. would not produce any effect in cast-iron.

5 The tests of the famous Crane valve so often quoted are no proof of superheated steam being responsible for the failure. Test bars from the broken valve were compared with test bars taken from the same heat that the valve was made from, and the valve was said to have weakened. This is no real test, because castings from different parts of the same heat, or, in fact, different parts of the same casting are known to vary in strength, and it is quite likely that fittings passing saturated steam, if compared on the same basis, would be found to have suffered greatly from the effect of saturated steam! It is unquestionably true that this valve must have been subjected to other influences besides superheated steam. It is rather remarkable that the body of the valve is said to have been weakened more than the flanges—the reason given being that the metal of the body was nearer the superheated steam. Is it not more reasonable to suppose that the metal of the body weakened more than that of the flanges because it was subjected to greater fatigue on account of expansion and contraction of the pipe?

6 The writer's experience with a great number of steel fittings used for pressure parts of superheaters exposed to hot gases, has led him to conclude that the metal in steel-castings is anything but satisfactory for fittings. It unquestionably has greater tensile strength than cast-iron, which appears to be its only advantage. On the other hand, it is difficult to get steel castings sufficiently homogeneous to hold the pressure. A large percentage of castings are "doctored" before leaving the foundry, but new openings frequently develop on test after machining, and even after the castings are in place, causing the charge to be made that the castings have not been tested before sending out. This fact is further evidence of strains developing in service, other than those produced by internal pressure, which open up cavities or spongy places not discovered by shop test. Steel castings vary greatly in toughness, as shown by the great variation of elongation on test; others are so hard that machining is very difficult. While they can be bought on very careful specifications to guard against these faults, there is always the chance of porosity. The high tensile strength of the steel is not a necessity, and cast-iron made to careful specifications is amply strong. It machines well, is not porous, and can be relied on to hold the pressure.

7 Care should be exercised in the design of pipe lines to guard against straining the fittings from movement of the pipe due to expansion and contraction. Where long radius bends are the means of taking up this movement, pipe of the lightest possible weight consistent

with safety should be used, thereby lessening the force required to spring the pipe. With properly connected flanges, full weight pipe is amply strong for all ordinary working pressures, and if drawn tubing is used, even lighter metal may be adopted. In this connection the design and arrangement of the superheater is of great importance, and should be such that sudden and frequent changes in the temperature of the steam do not occur; otherwise the changes in the length of the pipe will be more frequent, resulting in a more rapid fatigue of the metal of the fittings.

8 A better way of taking care of expansion than with long radius bends, is to use ball and socket expansion joints, which have the additional advantage of reducing the amount of piping.

9 The writer agrees with Professor Hollis in charging strains due to expansion and contraction with the failure of certain fittings, and with Mr. Mann when he charges inferior fittings with the cause of failure in other cases and recommends the use of a good cast-iron containing a percentage of steel scrap for fittings passing superheated steam. This is entirely in accord with the writer's experience.

H. S. Brown believed the troubles with cast iron would be eliminated if the temperature could be kept constant, and further said:

2 I think the discussion boils down to this, that under certain conditions steel castings will give a more satisfactory performance than cast iron. The company with which I am connected has found it necessary to replace a large number of cast iron fittings with steel castings, where superheated steam was used; and the performance of these steel fittings, under the same conditions under which the cast iron fittings were working, has been satisfactory.

3 In a large number of other plants where cast iron fittings are used with saturated steam, the design of the piping is such that the stresses set up on account of expansion and contraction are very much worse than in this system; and we do not get into troubles as we did in using superheated steam. It may be that steel fittings will form a more practical and less expensive way of taking care of the conditions set up by the use of superheated steam than elaborate precautions in the way of expansion joints and the like.

E. H. Foster. Cast-iron is much too useful a metal to receive general condemnation for steam pipe fittings, whether for superheated or saturated steam, without very good reasons and the writer is firm in this opinion that such reasons have not yet been advanced.

2 Having devoted the greater part of his time for the past ten years to the study of superheated steam and the manufacture of superheaters, the writer has eagerly followed up every report of the failure of a steam pipe fitting, where superheated steam was used, and it can fairly be said that no instance has yet occurred where the weakness has not been readily explained by the poor quality of the iron, or by lack of provision for expansion and contraction without straining the metal. The many instances where cast-iron fittings are habitually subjected to steam of varying degrees of superheat up to final temperatures close to 1,000 deg. fahr. leave no doubt that good cast-iron is equal to, if not better than, any other metal for making steam fittings for superheated steam as well as for saturated steam, especially in smaller sizes.

3 In the writer's experience it is as important to have regard to the mixture of the iron to be used in cast-iron fittings as it is to secure the proper mixture for concrete work.

4 The suggestion that better provision should be made for free expansion and contraction of steam pipes, is, in my opinion, very much to the point. More care applied to this feature of the design of power plants would remove entirely from the shoulders of cast-iron the odium of being unsuitable for carrying superheated steam.

L. B. Nutting stated that superheaters installed by his company nine years ago, and since then in constant use, have caused no trouble and have not changed their dimensions. These superheaters were made entirely of cast iron, the tubing having a smooth bore and corrugated exterior.

2 He also reported a great many superheaters installed and in operation delivering steam at a temperature of 1000 deg. fahr. On these the users have employed, without any distortion or without any evidence of weakness developing, standard makes of cast iron valves (globe valves and angle valves) under 1000 deg. final temperature. But the temperature is maintained at 1000 deg., without a variation of 25 deg. These illustrations seem to trace the cause of the trouble with cast iron fittings directly to widely fluctuating temperatures.

3 In regard to Mr. Mitchell's suggestion that provision should be made to obviate troubles from varying temperatures on cast iron Mr. Nutting asked, why not make provision to keep the temperature constant. The art of superheater construction has advanced to such a point that a uniform temperature should safely be counted

on. The plant Mr. Primrose referred to, a 20,000-h. p. boiler plant has a record of variation not exceeding 10 deg. either way from the desired amount at any time during the year, although the loads had a fluctuation of from 5000 to 35,000 kw.

ANDREW LUMSDEN.[1] In one case we have eight boilers of the Babcock & Wilcox type, equipped with heaters part of which were made and installed by the boiler company. These boilers were all connected to one 12 in. main through long radius bends, valves, tees, etc. On the superheaters installed by the boiler company there were usually 150 deg. of superheat and on the others about 90 deg.

2 When this plant had been in service about two years some of the fittings in the main were found to leak just back of the fillets and small cracks were discovered extending around one side of the tees. Some long bolts were made to go the whole length of the tees and through the end flanges, using them to make the joints. Steel tees were also ordered of the same dimensions as the cast-iron ones to replace all the fittings in the main. When the old fittings were removed, however, it was found they were from $\frac{3}{8}$in. to $\frac{1}{2}$ in. longer than when first installed. This is a turbine station and they have had quite a little trouble with the admission valves on some of the turbines, those directly opposite the boiler carrying the 150 deg. superheat giving by far the most trouble.

3 At another plant there are boilers of the Babcock & Wilcox type and Curtis steam turbines, installed seven years ago, with a separately fired superheater on which exhaustive tests were made. The temperature of the steam leaving the superheater reached as high as 750 deg. The superheater was run for about six months and at the end of that time all the copper gaskets in the main were destroyed and the joints had to be remade. The superheater was shut down and has not been operated since.

4 The writer visited this plant a few days ago and found that no large joints had been made since the superheater was shut down. There are about ninety joints ranging from 8 to 12 in. diameter and none have leaked, but three 12-in. valves were leaking badly through the body on the under side and about the point where the seat rings are screwed in. These valves are laid on their sides and are on the boiler side of the superheater and have never had superheat in them nor in

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the writer's judgment can their troubles be due to expansion as particular care was taken to allow free movement in all the piping of the plant.

5 At another plant where they have Babcock & Wilcox boilers, Curtis turbines, etc., they have carried 150 lb. steam pressure and 150 deg. of superheat for about six years, with cast iron fittings, etc., and have had no trouble with the fittings. The valves have given them some trouble with loose seat rings and by being badly cut, and some of them have been replaced.

John C. Parker. Professor Hollis draws attention to the necessity for greater allowance for expansion in piping for superheated steam. This is important and where sufficient flexibility cannot be put into the design expansion joints should be installed. My experience accords with his statement that cast-iron fittings have been largely and successfully used for superheated steam.

2 Six or seven years ago I was called on to furnish superheaters with some of our boilers but could find none in the market to meet my ideas of what a superheater should be. A design was worked out and forty or fifty thousand horsepower of boilers have been built with these superheaters. Two plants are above ten thousand horsepower. In six years experience we have had no trouble either with cast-iron or steel fittings, valves or cylinders. I ascribe the result to the steadiness of the superheat and to the fact that condensed steam in the superheater is not intermittently carried into the steam line.

3 In one of our first installations the men started to flood the superheaters without my knowledge whenever the boilers were banked and the result taught me the effect of suddenly injecting water at 360 deg. fahr. into piping and headers which had been raised to 500 deg. fahr. Leakage started at the joints but stopped as soon as the practice was stopped.

4 I believe there is no connection between the troubles which I have been cognizant of with some designs of superheaters and the expansion of the steam mains. I believe the troubles have been due solely to fluctuations in temperature and temperature shocks caused by frequent injection of condensed steam from incorrectly designed superheaters. I recently went into a plant where a superheater had been in use for about four years. It was an independently fired superheater and the engineer had had so much trouble with piston rings in an engine with poppet valves designed especially for superheated steam, that he had cut the superheat from 600 deg. fahr. to

500 deg. fahr. and then to 400 deg. fahr. He had his ideas centered on the point at which the trouble occurred (the cylinder and rings) and would not believe that it was due to fluctuations of temperature. I finally pinned him down to the statement that "the temperature could be controlled perfectly but you had to watch it like a cat."

5 There is a superheater in the market that uses cast-iron to protect wrought iron tubes. I have seen some of these removed from boilers on account of overheating and, while the cast-iron had been red hot it had cracked less than some steam pipe fittings which had been subjected to water jets and fluctuations under 600 deg. fahr.

6 I do not think conclusions can be drawn from Professor Miller's experiments. It would require at least half a dozen tests of the same sample of cast-iron at progressively increasing temperatures and periods to obtain results of value. Ten of the tests show increased strength of cast-iron while all the steel has lost strength. One steel test (100,000 lb.) is unreasonable.

7 It is unfortunate that Mr. Mann has not given us plans of boilers and superheaters and steam piping, and such data regarding the conditions under which the fitting troubles occur, as would permit more intelligent study. I note that steel fittings have failed in some cases. This would indicate water jet action, since we have never had to renew a single steel header in our superheaters.

8 We have sixteen 800 h.p. boilers with superheaters directly over the fire running at 175 lb. pressure and up to 170 deg. superheat with no such trouble as Mr. Mann mentions in Par. 12.

Albert A. Cary said that after investigating a number of plants having trouble with the use of superheated steam, he had been led to the conclusion that many if not most of their troubles have been due to bad design in the piping arrangements.

2 Far greater care and better judgment is called for in designing pipe systems for superheated steam than for similar systems using saturated steam, as the strain due to expansion and contraction is greatly increased. The piping on each side of every offset should be carefully considered to see that excessive stress is not thrown upon the flanges and threads by the lever which is developed there. Several special forms of flanges which avoid the screw connection are now used to excellent advantage, with high superheat.

3 Continued flexing on one side of the flanges of fittings, due to the cooling and high degree of heating of the pipe system as steam is turned on and shut off will cause ruptures not unlike those shown in

the illustrations accompanying these papers and will be apt to change the internal structure of the metal itself.

4 As higher velocities are permissible, in pipes carrying superheated steam, than in those for saturated steam, somewhat smaller piping can be used to excellent advantage, not only decreasing the cost, but also increasing the flexibility of the pipe line.

5 Considerable care must be exercised in flexible pipe bends, which should be bent to large radii, and placed in the most effective positions with a proper anchoring of the pipe on either side of the bends. Careful supervision must be exercised in seeing that the pipe fitters make up their pipe lines in such a way as to avoid any severe springing of the pipe in order to make the flanges of the joints register properly, one against the other. Undoubtedly, neglect in these particulars of pipe design and pipe fittings is responsible for a very large percentage of the failures found in the fittings and joints in superheated steam plants.

6 I have been led to consider the handling of superheated steam in power plants under two headings, first superheated steam having a total temperature below 500 deg. fahr.; second, superheated steam above this temperature. The first-named quality of steam, with a total temperature below 500 deg., will be found better applicable to old plants, in which it may be newly introduced, and in many new plants. With such steam we may use the ordinary high-grade fittings used in saturated steam work, with some modifications.

7 The high-temperature superheated steam in power plants is more especially adapted to installations where high-pressure steam is required for steam turbines.

8 Mr. Cary referred at some length to the possibility of cast iron being affected by heat under stress, calling attention to the discoveries under the microscope of the change in physical condition of alloys produced by heat treatment, and advocated the carrying out of experiments along these lines.

W. E. Snyder. I may be able to touch upon certain particular phases of the papers and the discussion, in such a way as to contribute some of the results of actual experience covering a wide variety of conditions and several years' practice. The consideration of this subject in the discusssions seems to have broadened to include the effect of unequal heating of metal and also the designs of systems of steam piping. These matters are both directly related to the use of cast iron fittings for superheated steam, as failures may in

some cases be due to the improper design of the steam piping; also under some conditions to unequal heating of such irregular castings.

2 A common connection between engine and main steam pipe is by a branch running horizontally and at right angles to the main pipe, out directly over the high-pressure cylinder and turning down by a bend to connect with the throttle valve on top of the cylinder. When this branch is long the expansion in the steam line does not exert any harmful effect in the throttle valve, but the expansion in the branch is taken up by the change of curvature of the bend over the throttle valve, and this puts a strain directly on this valve. In two or three instances where this kind of connection was in use, the throttle valves were cracked immediately under the flange, and serious accidents narrowly averted.

3 Where the branch to the engine is short the expansion in the branch itself does not require any consideration, but the longitudinal movement of the steam main due to its expansion and contractions, transmits strains through the branch pipe directly to the throttle valve and flange on the steam chest. In one instance this resulted in a very serious accident, as the cast iron flat top of the steam chest was broken in by the expansion of the main steam pipe several feet away.

4 In another installation a 24 in. cast iron Y with an 18 in. branch split in the fork of the Y, while under 150 lb. steam pressure. Fortunately it was possible to take the line out of service before the fitting exploded, but it was a very narrow escape. All the accidents mentioned above were the direct results of the installation of systems of steam piping without proper consideration of the effects produced by expansion and contraction. All were in systems using saturated steam, and they emphasize the necessity of using great care in arranging the piping that the expansion and contraction may take place without throwing the severe strains on the cast metal members, which are always liable to failure under such conditions. Consideration of this feature of design is of still greater importance in piping systems using superheated steam, on account of the higher temperature used and the consequently greater expansion. The avoidance of expansion strain on castings in a system of steam piping is of fully as great importance as is the selection of the material from which these castings are made.

5 The effect of unequal heating of metal has been investigated by engineers in the French Navy (See Marine Boilers by Bertin &

Robertson, p. 201). The theory advanced there, which seems reasonable and is also confirmed by experience, is this: When one side of a piece of metal or a boiler tube is heated to a higher temperature than the other, the hot side tends to expand, and the expansion is resisted by the metal on the cold side. This condition puts the metal on the hot side in compression, and the metal on the cold side in tension, and if the temperature difference is great enough the metal will be strained beyond the elastic limit. When the hot side is allowed to cool it is shorter than the cold side because of the strain beyond the elastic limit which has been undergone by both sides. This results in the piece taking a permanent set, or becoming "bow shaped" away from the side that has been heated.

6 The bend away from the fire of boiler tubes in some types of boilers after they have been in service for some time, seems to be a good example of the results of unequal heating. Another example is the cracking of the large cast iron mud drums used in some types of water tube boilers. Under ordinary operating conditions, in boilers having vertical baffling, the hot gas does not come in contact with the mud drum of the boilers until it has passed at least twice across the tubes, and has thus been greatly reduced in temperature. At times, however, holes are formed in the front baffle, or through the top of the bridge wall allowing the hot gases to pass directly from the furnace to the back part of the boiler setting, where they strike the cast iron mud drum, heating it to a considerably higher temperature on the front side than on the side away from the fire. These conditions have resulted, in a number of instances, in causing the mud drum to crack perpendicular to its axis, causing serious accidents.

7 This matter of the unequal heating of metal is one of the most serious with which designers of large engine cylinders have had to contend. Features of the design of pipe fittings are very similar to those mentioned in the design of gas-engine cylinders, the irregular castings having flanges and other forms of construction which make it practically impossible to avoid having the metal considerably thicker in some places than in others. This irregularity causes internal strains in the metal when heat is applied to one side. It has been the experience of European designers of gas-engine cylinders that one of the greatest difficulties they have had to overcome is this one of distributing the metal so as to avoid the small cracks resulting from irregular expansion, which destroy the cylinder. Where trouble has occurred in the use of cast iron for large fittings in superheated-steam piping, it is possible that the experience of the gas-engine engineers will suggest the remedy.

8 As bearing upon the use of cast iron for superheated steam, particularly upon the much discussed question of the possibility of having superheated steam that is in contact with water in the boiler, an experience of the speaker may be of interest.

9 A large furnace used for heating slabs for a plate mill was equipped with a small vertical Cahall boiler for the purpose of utilizing part of the waste heat. This furnace was fired with under-feed stokers, using forced blast, so that it was possible to obtain a very high temperature both in the furnace and in the boiler, also in the stack. The boiler was set in the usual way for waste heat, i.e., with the large end down. The steam pipe was connected to a flange on the top of the boiler, this connection being made inside the conical-shaped base of the stack which rested on top of the circular boiler setting. This arrangement put a cast-iron elbow on this steam pipe, and about two or three feet of pipe on each side of the elbow in the hot gas directly over the upper drum of the boiler.

10 Tests on this furnace and boiler were continued for two weeks, observations being taken every 30 minutes. Frequently the stack temperature would rise to 1000 and 1100 deg. fahr. The thermometer on a Carpenter throttling calorimeter, connected to the steam pipe just outside the stack breeching mentioned above, ranged from 380 to 600 deg. fahr., depending on the rate of working of the furnace. This variation at times occurred very rapidly, and at the time the thermometer readings were high, the steam escaping from the calorimeter was as completely invisible as though it were natural gas. For twelve hours in succession the average superheat of the steam was 140 deg. and during the entire time the tests were being made, the superheat of each 12-hr. period averaged 120 deg. or over; the steam pressure being about 95 lb.

11 This boiler has been in operation under conditions similar to the above for at least 15 years. The cast-iron elbow and flange at the top of the boiler, although subjected to such severe service as that described, has never given any trouble. A number of other Cahall boilers using blast-furnace gas, with steam pipe connections made in the same way, have been in operation for about the same length of time, and no troubles have occurred due to the fittings. The service under blast-furnace gas conditions are not so severe as the heating-furnace installation described above, on account of the stack temperature being somewhat lower, from 700 to 900 deg. The heating-furnace conditions mentioned above are unusually severe and for that reason have been described fully. It may be added that the

boilers using blast-furnace gas-produced superheated steam, notwithstanding that the water level was only a short distance below the connection to which the calorimeter was attached. (This must not be understood as being a special feature of the Cahall boiler, as in fact it is only incidental to its operation under these conditions.)

J. S. Schumaker mentioned that in the cases cited no difficulty had been experienced with the fittings of superheaters, cast iron or otherwise, but that there had been a great deal of difficulty with steam-pipe fittings. This seems to be the result of high temperature on one side of the fitting only. In the superheater itself the temperatures are balanced, to some extent at least.

Dr. D. S. Jacobus. In a large power plant that I have in mind, where the fittings are all of cast-iron, and where the superheat averages 150 deg. fahr., repeated examinations have failed to reveal any deterioration. In other cases, however, where there has been less superheat, and even where a single boiler with superheated steam has been connected into a common main with a number of other boilers furnishing saturated steam, there has been every indication that a small amount of superheat has had an injurious effect. It therefore seems that a difference in the quality of the cast-iron may affect the results, and by making a careful study of the matter and knowing the analysis of the cast-iron there is a possibility that its action under superheated steam may be predicted. In the meantime, we are furnishing cast steel fittings for all superheated steam work, as we do not know of a single case of the failure of such fittings that can be attributed to the action of tl e superheat.

2 The stresses due to expansion, as pointed out by Professor Hollis, may tend to produce failures. In the case of fittings broken in superheated steam lines we have found there was a stress at the point of rupture entirely apart from the stress produced by the steam pressure. In the ordinary flanges the tension of the bolts produces cross strains and the fittings give way where they would naturally fail through this strain. We have given considerable thought to the construction of flanges in which such cross strains are eliminated, but have not pushed the matter forward as we have decided to eliminate all doubt as to the safety of the fittings by employing steel castings.

3 Professor Miller's tests bear out what we have observed regarding the different results to be expected from cast-iron, as they show that although there is a general falling off in strength in cne case the

cast-iron specimens did not lose in strength by being subjected to a high degree of superheat. In connection with such tests it would be interesting to investigate the action of superheat when the metals are under stress.

4 Mr. Mann's conclusion that gun iron is better than cast steel is indeed interesting, but we would not think of changing our present practice of using cast steel until gun iron is thoroughly tried out in the practical field and demonstrated all right for the work. The proper method of determining the quality of the gun metal which is used must also be developed by the necessarily slow process of observing the action of the fittings in service. It would indeed be a simple matter if bids for the fittings could be based on an analysis of the metal, and I hope Mr. Mann may be right in this belief.

Prof. H. F. Rugan. While investigating the phenomenon of the increase in cubic dimensions of cast iron as a result of repeated heatings it became evident that the test pieces deteriorated in strength. I am of the opinion that the influences at work producing such growth at high temperatures are the same that cause the failure of cast iron fittings at lower temperatures, say at from 500 deg. fahr. to 600 deg. fahr. The effect of the higher temperatures is merely to increase the extent of the changes, producing a maximum growth per heat.

2 Further experiments to determine the length of time required to produce maximum growth developed the fact that a change in the temperature was necessary to produce continued growth. No apparent difference in growth was observed between pieces heated at the same temperature for periods of 3 hours and 17 hours respectively.

3 The test pieces were heated in cast iron muffles, carefully luted with fire clay, to protect them from contact with the furnace gases, to a temperature of from 850 deg. cent. to 950 deg. cent.

4 Experiments were made with nine iron carbon alloys (A to I) containing no graphite, the carbon content changing by 0.5 per cent from 4.03 per cent to 0.15 per cent. Other constituents were low and constant. Four bars of each alloy were cast in both sand and chill moulds. These proved to be all white irons, the samples with low carbon content being full of blow holes. No growth was observed in any save the sample A which contained 4.03 per cent carbon. This sample shrank for the first 12 heats, afterwards expanding, ultimately becoming 6.88 per cent larger than its original volume.

5 Four alloys (J to M) were also tested. Of these J, K and L were grey irons while M was a white iron. It was observed that M

followed along lines closely approximating the action of A, shrinking slightly during the early heats but growing after 12 to 19 heats had been taken; ultimately becoming 6.2 per cent larger than the original. Pieces of the bars from which the A and M test pieces were made, were inserted in the muffle to be sampled for chemical analysis after successive heats. These analyses showed that the appearance of free carbon (or temper carbon) coincided with those heats which produced growth in the test pieces. Free carbon was in this way proved to be in some way an indispensable factor in the growth of cast iron when under heat treatment.

6 The grey irons J, K and L, grew from the start, and their progress indicated a close relation between their respective growth and their silicon content.

7 To check these indications a series of alloys, with all the constituents constant save silicon, having the following analyses, were used to test the part played by silicon:

Alloy	Total Carbon	Combined Carbon	Graphite	Si.	Mang.	Sulph.	Phos.
N	3.98	0.64	3.34	1.07	0.25	0.01	0.013
O	3.98	0.68	3.30	1.79	0.23	0.01	0.013
P	3.79	0.30	3.49	2.96	0.25	0.01	0.012
Q	3.76	none	3.76	4.20	0.27	0.01	0.012
R	3.79	none	3.79	4.83	0.30	0.01	0.012
S	3.38	none	3.38	6.14	0.30	0.01	0.013

8 It will be observed that the total carbon in the series is approximately constant, that alloys N and O contain about the same amount of combined carbon, that alloy P contains about half the quantity, and that the remaining alloys contain none at all. The silicon in O and R is 0.2 per cent lower, in Q, 0.2 per cent higher than was desired. The remaining constituents are satisfactorily low and constant.

9 Test pieces N to S, measuring 6 in. by about 0.88 in., were machined from the castings. They were not taken from similar portions throughout, but haphazard, some from the gate, others from a riser either near to or at some distance from the gate. When the growth of these alloys was investigated it became evident that the locations from which a test piece had been cut had a considerable influence on the rate of expansion. It was found that specimens taken from the gate end of the casting grew more rapidly than those taken from the top of the riser.

10 In test pieces from the same part of the bar, however, these inequalities disappeared and a like growth was obtained in each alloy. A slight falling off was observed in the closer-grained irons.

11 The results obtained are plotted in Fig. 1, the coördinates being percentage of growth and number of heats. In this way the rate of growth is clearly seen. In the case of samples N, O and P, curves are plotted from the data obtained. It will be observed that the growth

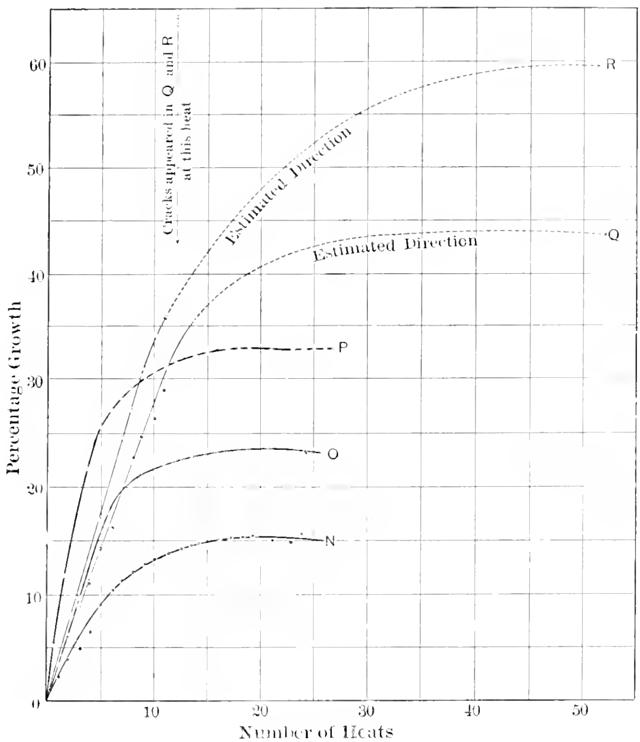


FIG. 1 CURVE SHOWING RATE OF GROWTH OF ALLOYS N TO S

is rapid at first, diminishes after about the seventh heat and stops at the sixteenth heat.

12 In the case of Q and R curves are plotted in full lines from the data obtained up to the point at which cracks appeared, viz. the twelfth heat. Beyond this the direction of the curves can only be guessed and this is indicated by dotted lines. The following table summarizes the results:

Alloy	Percentage of Silicon	Percentage Growth on Heating
N	1.07	15.40
O	1.79	23.46
P	2.96	32.85
Q	4.20	43.90
R	4.83	59.50
S	6.14	63.00

13 It is quite clear from these tests that silicon is a most important constituent of cast iron from the standpoint of growth under repeated heatings. If the ultimate growths and percentages of silicon are plotted as coördinates, the curve in Fig. 2 is obtained, which shows that, broadly speaking, the growth is proportional to the percentage of silicon.

14 To settle the question as to the influence exerted by graphite, and at the same time determine if iron-silicon alloys, containing little carbon and no graphite, would grow, three alloys (T, U and V) were experimented with, having the following analyses:

Alloy	Silicon	Carbon	Mang.	Sulp.	Phos.
T	0.65	0.17	0.17	0.045	0.017
U	1.10	0.18	0.19	0.049	0.022
V	2.71	0.19	0.20	0.051	0.033

15 Microscopic examination showed in all three cases a solid solution of iron silicide in iron. There were no traces of graphite or any other structural constituent.

16 Machined bars were heated fifteen times under the same conditions as the previous alloys. A summary of the final values is contained in the table below:

Alloy	Percentage Silicon	Percentage Change of Volume after Fifteen Heats	Percentage Change of Weights after Fifteen Heats
T	0.65	−0.025	−0.04
U	1.10	0.000	−0.03
V	2.71	+0.394	−0.02

17 It will be seen that the only alloy of the three which showed any tendency to grow was V, with 2.71 per cent of silicon. The expan-

sion, however, was very slight, and compared with that of P (2.96 per cent silicon and 3.79 per cent carbon) after the same number of heats was almost negligible, amounting to but 0.394 as compared with 31.35 per cent, the mean figure of P and PP.

18 Alloys K, N and P correspond closely to alloys T, U and V in silicon content. They also contain about 3.9 per cent of carbon,

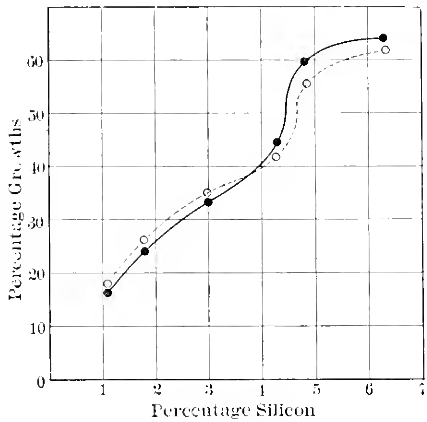


Fig. 2 Curves illustrating Relation between Percentage Growth and Percentage Silicon

mostly in the form of graphite, as compared with a mean figure of 0.18 per cent carbon, none of which is present as graphite in the other series. A comparison can thus be made between the changes of volume of the two series under similar tests after fifteen heats, by means of the following:

Alloy	Carbon	Silicon	Per Cent Change in Volume	Alloy	Carbon	Silicon	Per Cent Change in Volume
T.........	0.17	0.65	−0.025	K..........	3.90	0.69	+ 5.40
U.........	0.18	1.10	0.000	N..........	3.98	1.07	+15.20
V.........	0.19	2.71	+0.394	P..........	3.97	2.96	+31.35

19 This comparison serves to emphasize anew that free carbon, even in the form of graphite, is one of the essential factors in the growth of cast irons under heat treatment. The previous series of alloys, however, N to S, brought out clearly the fact that in the constant

graphite series the growth is roughly proportional to silicon present, graphite becoming merely the agent or forming the avenues by means of which the silicon present can be acted upon. It is clear, therefore, that both graphite and silicon are involved in these changes of volume after repeated heatings.

20 A sample of test piece S, known as "S $\frac{1}{2}$," was heated to constant volume in vacuo. This resulted in a shrinkage of 0.04 per cent. The same sample was afterwards heated in the muffle to a constant volume, when a growth of 67.70 per cent was obtained. Fig. 3 shows curves plotted from these data. It will be seen that S $\frac{1}{2}$ grew rapidly during the later heats, with no cracks developed, and the sample retaining its original form throughout. S, however, grew rapidly during the earlier heats, cracks developing during the first heat, and finally breaking in two.

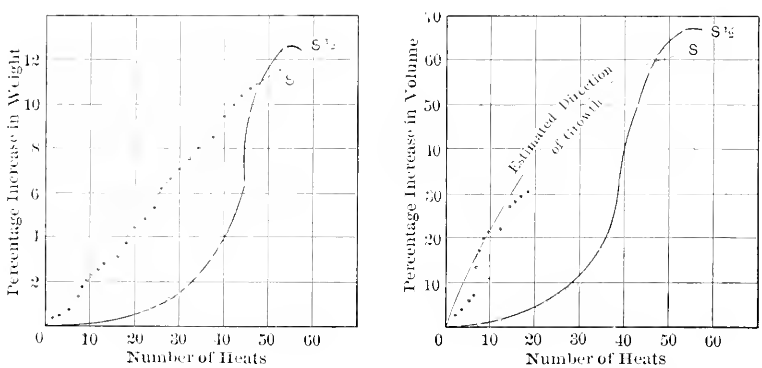


FIG. 3 CURVES SHOWING PERCENTAGE INCREASE IN WEIGHT AND VOLUME AND NUMBER OF HEATS: TEST PIECES *S* AND *S* $\frac{1}{2}$

21 Mr. A. Wolfe, superintendent of motive power of the United Railway and Electric Co., Baltimore, commenting upon the growth and final failure of some fittings in one of their power houses says, "The temperature was not constant, varying between that of the temperature of saturated steam at 175 lb. per sq. in. to superheated steam running between 500 deg. fahr. to 550 deg. fahr. total temperature."

22 From the experiments I have made there is considerable evidence indicating that gray cast iron subjected to changing temperatures from 450 deg. fahr. and up gives evidence of an oxidation of the silicon present, forming silica in a micro-crystal form, which upon

cooling causes a disintegration of the surface exposed, ranging generally along the planes formed by the graphite, changing an apparently solid wall into one showing many cracks. It is the constant recurrence of these conditions, produced by the changing temperatures, that, in time not only produces growth, but breaks down the structure of the metal.

23 The experiments conducted by Prof. E. F. Miller were so treated, cooling down each night to the temperature of saturated steam. No mention is made of any growth of these specimens. One would expect to find a marked relation between growth and loss of strength.

24 In a comparison between gray iron samples, those subjected to a heating and cooling treatment totaling 1000 hours would become weaker and larger than those kept constantly at the temperature of superheated steam for a like period. I believe that actual contact with steam is not a necessary condition in this experiment, neither is it a comparative test of the metal, which in service, has one surface exposed to atmospheric conditions.

AUTHOR'S CLOSURE

Prof. Ira N. Hollis. The discussion of these papers brings out certain interesting and valuable conclusions which cannot fail to assist in the proper use of cast iron for parts of machinery and boilers. Previously existing differences of experience with this metal under a high temperature are shown to be due to fundamental differences of chemical composition or to variations in the temperature. From this point of view, existing data, even though conflicting, can probably be reconciled. The following conclusions as the result of the papers and discussions may be studied with profit in connection with new construction.

a Cast iron varies in its behavior under high temperature, starting from about 450 deg. fahr. In many cases it deteriorates in structure and strength to a marked degree.

b The effect of high temperature is independent of the medium producing it, whether superheated strain, hot gases or solids.

c. The change of structure or deterioration is much increased by a fluctuating temperature.

2 Where the temperature is constant, even though as high as 600 or 700 deg. fahr., the change in cast iron is not serious enough to pro-

hibit its use, but where the temperature varies considerably, the metal is certain to develop cracks and distortion that render it unsuitable for steam pipes and other parts under steam pressure.

d Cast iron of certain chemical constituents increases materially in volume when subjected to fluctuating temperatures above 500 deg. fahr.

e The chemical composition of the cast iron has a material bearing upon the change of shape and volume and upon the development of imperfections.

3 Certain facts in this connection are well shown by Professor Rugan's experiments. As he states, cast iron containing only combined carbon does not change even under high fluctuating temperatures unless the carbon begins to separate into a graphitic form. Free carbon is one of the factors assisting in the deterioration under high temperature, especially when associated with silicon. The latter seems to be the chief cause of increase in volume. Where the free carbon is constant, the growth in dimensions is roughly proportional to the percentage of silicon.

f The use of cast-iron fittings for superheated strain is inadvisable where the temperature is likely to fluctuate, but it can be safely used where the temperature is to be constant.

g Cast-iron fittings should not be placed in any parts of a steam-pipe line where there are serious bending stresses in addition to the stresses produced by internal pressure, unless the combined stresses are fully allowed for, or neutralized by expansion joints.

GAS POWER SECTION

REPORT OF STANDARDIZATION COMMITTEE

PUBLISHED IN THE JOURNAL FOR DECEMBER 1909

DISCUSSION PRESENTED AT ANNUAL MEETING 1909

DR. D. S. JACOBUS. I would ask why it is that if the engine, producer and other apparatus, are put in by the same party, it is not necessary that data shall be taken of the efficiency of the producer, as differentiated from the efficiency of the engine, etc. I may have misunderstood that feature of the report, but I remember that there was a severe criticism of a paper presented last year upon a test of a steam power plant, in which simply the fuel and the final output were measured. It was held that what was really needed was the intermediate data to show how the efficiency was obtained.

PROF. R. H. FERNALD. In Par. 24*a* of the report it is recommended that the sample be dried at 210 deg. fahr., or just below the atmospheric boiling point. The code of the American Chemical Society requires, I believe, a temperature of 105 deg. cent., or a little above boiling point, which is the Government specification at the present time.

2 One of the most difficult things is to judge the conditions of the producer bed, as the report implies (Par. 25). It is so important that a special bulletin, No. 394, has just been prepared for the technological branch of the geological survey report dealing entirely with the question of the bed. Tests of a 250-h.p. producer carried on for 60 hours continuously, showed that this length of time was not nearly long enough to give conclusive results.

3 In Par. 52 reference is made to the time required to reach the steady state in the case of large engines, which raises a query as to

the division between large and small engines. This depends on individual practice. A 250-h.p. engine might be large from one point of view and small from another.

4 In Par. 55 the committee states, in discussing the speed, "this may be checked by instantaneous readings or intermittent countings taken at regular intervals and numerically averaged." I think that clause should read *must be*. It is almost imperative in any test that we should have a definite check on the readings.

5 In Par. 60 attention is called to "how the cards shall be intergrated," as one of the important considerations. It is difficult to determine exactly the factors which influence the mean effective pressure of the cards. It is easy to have the indicator card so integrated that the brake horsepower will be larger than the indicated horsepower, and the work must be handled with much care.

6 In regard to the characteristics of coal, it might be of interest to have on file a brief outline made for the American Society of Testing Materials. That society intends to draw up specifications on the basis of this outline. It may also be wise to have on record the Test Code adopted by the Government for the plant of the Geological Survey, which though relating to a special plant may assist the committee to get at the general points which have proved of special importance in these investigations.

7 The writer is in sympathy with the committee's recommendation of the use of high actual heat value for the gas, but would like to inquire in regard to liquid fuel. In questions relating to alcohol and gasolene, particularly with alcohol in which the percentage of water is from 15 to 50 per cent, the efficiency curves, which are very beautiful, when worked out on the basis of low heat value, are completely destroyed, and present peculiar characteristics when referred to the high basis. Does the committee intend to include the liquid fuels?

A. A. Cary. I think it is entirely wrong to consider a producer gas plant and its engine as one continuous piece of apparatus, or practically so. In the days of Watt, the engine efficiency was determined by pounds of coal per indicated horse power and what happened between the coal pile and the steam engine indicator was entirely neglected. Finally engineers began to realize that there was a boiler between the coal pile and the engine indicator, which had a part in that efficiency, and we are now careful to get at the efficiency of both boiler and engine. The individual efficiency of both producer and

engine should be determined in producer gas practice, for only in that way can improvements be made.

Edwin D. Dreyfus. In the re-arrangement of the report, from which in its final form such parts as have served merely to guide the committee in choosing and defining the most practical methods of testing will no doubt be eliminated, or incorporated in an appendix, a set of practical and standard tests should be distinctly defined, noting all refinements to be observed and the degree of accuracy to be attained.

2 The question of ratings (Par. 51) might be further elaborated. It is well known that altitude influences the power the engine is capable of developing, by reason of decreased density of mixture and the amount of heat entering the cylinder. Allowance for change in altitude should be specified, roughly about 3.3 per cent per 1000 ft. variation in elevation above sea level or point at which the normal rating is based, which is a fair average for fluctuating atmospheric conditions. Temperatures and pressures are additional factors. In some installations these items might be approximately selected, while in other cases conditions might arise to cause a considerable deviation from normal pressure and temperature. For example, if the supply pipes to the engines are located in a hot basement, and where the engine receives its supply through a holder located at an appreciable distance, maintaining a practically constant pressure, the drop in pressure in the delivery pipe becomes sufficient to cause the engine to pull several inches of suction at maximum load.

3 The question of reponsibility for the expense involved in conducting tests (Par. 87) is a commercial consideration and should not be included in the report. If, however, it is judged contrarily that this expense should be ascribed in some manner to protect the interest of the gas-power industry, the responsibility should then be differentiated in fairness to those builders who have already made large expenditures in proving the efficiency of apparatus, both in the field and in their shops. If small engines are concerned, witness tests may be readily made at the builders' works, which should involve no expense to the purchaser, provided they comply sufficiently with the requirements of the Standard Code of Tests. For large power work, the plant usually has an engineering staff capable of executing the tests as part of their duties, and in this case it would be optional to the builder to have representation when the tests were in progress, or at any time prior to the tests to provide normal adjustment of the apparatus.

4 Confusion in arriving at agreements (Par. 40*b*) and reporting the engine and producer tests separately would be likely to result from the abandonment of the use of the low value and of the distinction between the high and the low values of the gas. The low value has now been so extensively used in engine practice, that it should be clearly defined, and high and low values for different constituents of the gas also included. This will facilitate equating results from one basis to the other, where either one has been arbitrarily used in the past. This characteristic of the gas materially affects its suitability for the gas engine, due to the latent heat of the moisture formed in the burning of the hydrogen gases affecting the temperatures produced by the gas during combustion, and also a high hydrogen content limiting the compression pressures which can be safely used without danger of premature explosions. It should be given due regard, especially where the responsibility for the installation of the engine and producer is divided.

5 The percentage variation stipulated as permissible in the quality of the gas (Par. 40*d*) is more rigid than need be. The engine will work successfully on greater fluctuation, say from $7\frac{1}{2}$ to 10 per cent. Although a good producer will normally produce a quality of gas within these limits, somewhat greater variation might take place for short periods, which though causing no difficulty at the engine, may bring on a disagreement unless this condition is fully appreciated. Some attention should be given to defining distinctly how these measurements should be made.

L. B. Lent. Under general recommendations, Par. 77 reads: "All terms made in a guarantee should be defined. All guaranteed quantities must be capable of measurement and only one acceptable mode of measurement should be specified." Par. 79 reads: "Builders best serve their own interests when units are in terms most satisfactory to the purchaser, and involve only input and output for definite fuel, horsepower and time." If we were to put into a guarantee, which usually goes with the specifications of a gas engine, a description of all the apparatus used, stating the quantities and specifying the modes of measurement, our customers would be apt to entertain a proposition from some one with simpler specifications. If the Society sanctions a code in which the ordinary guarantee must be specified in legal phraseology, protecting the makers' interests until the apparatus is paid for, the guarantee would be far longer than the specifications and rather cumbersome. That part of the

report which deals with recommendations as to guarantees and other relations between manufacturers and builders, should be very carefully considered.

Dr. C. E. Lucke. This discussion will prove helpful to the Committee, and speaking for the Committee I can only hope there will be more of it. The more you consider these questions the more difficult they look. It is a simple matter to rise and recommend that a thing be done so and so, because you have not thought of any other way of doing it, but I suggest that you think about the report for six months, since it is only a preliminary report, and then after you have begun to realize the object of the report, write in your judgment of it.

2 The Committee has been nearly two years at this work and was many times seemingly ready to report, but did not because of the difficulty of the problems. The more views we can get on the questions at issue, the better. I have no intention of defending the report. My object is to ask you to give us your best judgment after mature deliberation, not before, because the questions are questions that are keeping courts busy all over this broad land today. The duty of the Committee was not to devise scientific tests for finding the physical actions involved—that is the business of the Code Committee. The business of this Committee was to eliminate misunderstanding between builders and purchasers, in so far as it could be traced to purely definitional causes from the use of terms having no accepted simple meaning, or from defining quantities not measurable.

3 I would therefore prefer not to reply to each of the suggestions but to let them go on record for the consideration of the Committee; but it is proper that I should say that there is the largest possible difference between tests for scientific information and the tests necessary to define a piece of apparatus sold. It is with the latter kind that this Committee deals and not with the former.

PRELIMINARY REPORT OF LITERATURE COMMITTEE

In accordance with a recommendation from the Chairman of the Meetings Committee of the Section, in a communication published in The Journal for October 1908, a Literature Committee was appointed at a meeting of the Gas Power Executive Committee, January 27, 1909. A tentative program for the work of the committee was outlined by Dr. C. H. Benjamin, *Chairman*, in a verbal report at the Spring Meeting of 1909. It is hoped to index all books, periodicals and transactions, domestic and foreign, dealing with gas power and allied subjects; also to present reviews of new books, and abstracts of important articles. Index cards have been prepared and are being filled by the members of the Committee, the work being divided under the following heads: reviews of French books and periodicals; reviews of German books and periodicals; reviews of Italian books and periodicals; revised list of articles appearing in English and American periodicals; reviews of English and American books as they appear; index of material on file in the library, both books and periodicals. The lists will be published from time to time in The Journal, with an index whenever the accumulation of material warrants.

GAS POWER LITERATURE

ARTICLES IN PERIODICALS[1]

ALCOOL, VINS E BIRRA, E. BOULLANGER. *L'Industria Rivista Tecnica, October 17, 1909.* $1\frac{1}{2}$ pp. *bdfA.*

Deals with the commercial aspects of alcohol power.

AUTOMOBILE-MUFFLER FOR FREE EXHAUST. *Le Genie Civil, September 25, 1909.*

Note abstracting article in La Vie Automobile, July 17, 1909.

CALORIMETRY OF GASES, METHOD AND APPARATUS FOR. *Le Genie Civil, September 11, 1909.* $\frac{1}{4}$ p.

Abstract of note presented by M.M. Lemoult and Jungfleisch to the Academie des Sciences. A simplification based upon loss of volume and consumption of oxygen.

CALORIMETRY IN THE THERMAL LABORATORY OF THE UNIVERSITY OF MOSCOW, METHODS OF, LOUGUININE AND SCHÖNKAREW. *Journal de Chimie Phisique, October 1, 1909.*

Note reviewing the French translation of this Russian work, according to it very high authority. Trans. by Ter Gazarian, Paris: A. Hermann, 1908. 192 pp.

CHEMISTRY SINCE LAVOISIER, HISTORY OF DEVELOPMENT OF. *Revue Universelle des Mines et de la Metallurgy, August 1909.*

Note reviewing French translation of fourth German edition (the first appeared in 1869), by Professor Ladenburgh of the University of Breslau. *Paris*, 1909. P. Hermann.

COMBUSTIBILI. *L'Industria Rivista Tecnica, September 26, 1909.* 1 p. *abdfA.*

From Chemiker Zeitung, 1909, p. 893. Considers mineral oil and gas for illumination, and developments of the oil, gas and coke industry.

EXPLOSIONS, GASEOUS. *Engineering (London), September 3, 1909.* Report to British Association at Winnepeg. $4\frac{1}{2}$ pp., 3 figs., 6 curves. *ceA.*

ENGINES, INFLUENCE OF COMPRESSION PRESSURE UPON THERMAL EFFICIENCIES OF GAS, W. A. TOOKEY. *Engineering (London), October 15, 1909.* 2 pp., 3 curves, 1 table. *cB.*

Discussion of report of Professor Burstall before Institution of Mechanical Engineers.

[1] Opinions expressed are those of the reviewer, not of the Society. Articles are classified as: *a* comparative; *b* descriptive; *c* experimental; *d* historical; *e* mathematical; *f* practical. A rating is occasionally given by the reviewer, as *A*, *B*, or *C*.

ENGINE, VARIABLE-STROKE PETROL. *The Engineer (London), October 15, 1909.* ¾ p., 3 figs., 1 table. *beB.*

A new engine for motor cars giving variable speed on direct drive.

ENGINE, 600-B.H.P. "PREMIER" GAS. *Engineering (London), November 19, 1909.* ⅓ page, 1 fig., *bC.*

Three-cylinder, direct-connected, gas-engine; water-cooled piston, engine mechanically oiled, etc.

ENGINES, LOW-TENSION IGNITION GEAR FOR GAS. *Engineering (London), October 29, 1909.* 1 p., 7 figs., *bC.*

Built for large engines; uses direct current from 65 to 220 volts. Intended to prevent possibility of pre-ignition.

ENGINE, NEW REVERSIBLE MARINE OIL. *The Engineer (London), December 10, 1909.* ¾ page, 3 figs., *bC.*

The "Bolinders" engine, by Jas. Pollock Sons & Co. Two-cylinder, two-cycle, hot-bulb, oil-injected, with reversing gear.

FUEL FOR AUTOMOBILES, BENZOL AS A CHEAP. *Le Genie Civil, October 2, 1909.*

Note abstracting tests reported in L'Automotor, June 26, 1909.

MOTORS, BALANCING AUTOMOBILE, *Le Genie Civil, September 25, 1909.*

Note abstracting article in La Technique Automobile, July 15, 1909.

MOTORS FOR DIRIGIBLES AND AEROPLANES, LIGHT EXPLOSION, Ch. Dantin *Le Genie Civil, June 5, 12, 19, 1909.* 18 pp., many figs. *bA.*

This article has not been inspected fully; but its great importance, as a résumé of French practice in this field, makes its inclusion inevitable.

MOTORS, SAFETY CRANK FOR HOISTS OR EXPLOSION. *Bulletin de la Société Industrielle de l'Est, July 1909.* 1 p.

Program for a competition for designs opened by the Association des Industriels de France contre les Accidents du Travail, 4 Blvd. St. André, Paris.

MOTORI A COMBUSTIONE INTERNA—MOTORI DIESEL REVERSIBILI. Ling R. Maraver. *L'Industria Rivista Tecnica, August 15, 1909.* 2 pp., 2 figs., *befA.*

Discussion of Diesel 3-cylinder gas engine.

MOTORI A COMBUSTIONE INTERNA. *L'Industria Rivista Tecnica, October 17 1909.* 2 cols., 1 fig., 1 table. *abcA.*

Shows complete sections of producer plant with engine of A. G. Dresdner Gas Motoren-Fabrik gia Moritz Hilledi Dresda.

MOTORE AD OLIO PESANTE. *L'Industria Rivista Tecnica, August 8, 1909.* 1½ pp., 2 figs., *befB.*

Discussion of gas engine of 3 to 15 h.p.

MOTORI A GAS E MOTORIA VAPORI. *L'Elettricista, May 15, 1909.* 2 pp. *afB.*

Discussion of advantages of gas for power plant economy.

Pump, An Internal-Combustion, Herbert A. Humphrey. *Engineering (London), November 26, December 3, 10, 1909.* 13 pp. 17 figs., 13 curves. Also *The Engineer (London)*, same dates. *bcfA*.

Paper before Institution of Mechanical Engineers. A new principle in pumping water and compressing air. The gas is exploded on the surface of the water in an explosion chamber in one end of a U-tube, the explosion forcing the water up in the other leg. No piston, connecting rod or crank, is used. Since the expansion stroke is longer than the compression, the gas can expand to atmospheric pressure.

Pump, The Humphrey Gas, W. Cawthorne Unwin. *Engineering (London), October 15, 1909.* $3\frac{1}{2}$ pp. 8 figs., 4 tables. *bcA*.

Report of tests on Humphrey internal-combustion pump, with general conclusions.

BOOKS

Engine, The Gas. F. R. Hutton. *Wiley, 1908.* 3d. ed. 562 pp., $5\frac{3}{4}$ x 9, 259 figs. $5.

A treatise on the theory, construction and operation of internal-combustion motors.

Engine, The Gas. Forrest R. Jones. *Wiley, 1909.* 447 pp., $5\frac{3}{4}$ x $9\frac{1}{4}$, 142 figs., 30 tables. $4.

Construction, operation, theory and performance of gas engines. Particularly good are the parts dealing with operation, ignition, adjustment and the location of troubles. Useful and practical for the operator as well as for the student.

Engine, The Gas. Cecil P. Poole. *Hill, 1909.* 97 pp., 6 x $9\frac{1}{2}$, folding tables. $1.

Elementary theory, construction, functions of various parts and operation of gas engines. Practical, useful and concise. A good introductory work of strictly limited scope.

Engine in Principle and Practice, The Gas. A. H. Goldingham. *Gas Power Publishing Company, 1907.* 195 pp., 6 x $9\frac{1}{4}$, 107 figs. $1.50.

A good elementary book for non-technical readers. No theory is included.

Engine Theory and Design, Gas. A. C. Mehrtens. *Wiley, 1909.* 250 pp., 5 x $8\frac{1}{4}$, over 200 figs. $2.50.

Elementary and superficial book, not reliable in its fundamental parts. Contains descriptive matter, and working drawings of small two-cycle and four-cycle engines.

Engine, Gas, Petrol and Oil, Dugald Clerk. *Wiley, 1909.* v., 1 VII + 380 pp., 8vo., 5 plates, 126 figs. *ee*. $4.

Historical sketch and thermodynamics of gas engines. A very complete study of the phenomena of gaseous explosions in closed vessels, with critical comparative examination of results. Followed by a study of explosion phenomena in actual engines by Clerk's "zig-zag" method—and the deduction therefrom of apparent specific heats of gases. Method developed for determining heat balances based on the "apparent" specific heat, and applied to various gas-engine tests. A valuable contribution to the theory of the gas engine—suitable for advanced students.

ENGINES, INTERNAL-COMBUSTION. R. C. Carpenter, H. Diederichs. *Van Nostrand, 1909.* 2d ed. 597 pp., 6 x 9½, numerous text figs. $5.

A comprehensive work of value, including the results of much German investigation for the first time in English. Four sections, dealing with: *a* theoretical considerations; *b* fuels and the phenomena of combustion; *c* construction and operation; *d* power estimation, tests and costs. A good text or reference book.

ENGINES, INTERNAL-COMBUSTION. Wm. H. Hogle. *McGraw, 1909.* 250 pp., 5½ x 8¾, 106 figs., 21 tables. $3.

Contains description and comparison of cyles; practical details of operation; starting devices; carburetors and vaporizers; producers; fuels and combustion; engine compression; the indicator card; design; governing devices; ignition; engine testing; report of tests. Treatment everywhere is elementary; rules of thumb only, given for design, and those only for small engines. Numerous inaccuracies.

ENGINES, CARBURETING AND COMBUSTION IN ALCOHOL. E. Sorel. *Wiley, 1907.* 269 pp., 5 x 8¼, 26 figs. *bcfA*. $3.

A valuable treatise on the properties of alcohol and on carbureting and explosions, based upon the author's extensive research. Unique in this field.

ENGINE, THE INTERNAL-COMBUSTION. H. E. Wimperis. *Van Nostrand, 1908.* 326 pp., 5½ x 8¾, 114 figs. $3.

Devoted primarily to the development of a new theory of gas engines, based upon variable specific heats of the gases. Much critical discussion of gaseous explosion experiments. Gas producers and engines are described rather briefly, and much information is given as to tests, costs, statistics and general data. Gasolene engines are also dealt with. The book takes up a number of special topics which are subjected to mathemetical analysis; as for example, the inertia effect in indicators, the theory of jet carburetors, etc. It is interesting and suggestive throughout and would be most valuable to advanced students.

MOTORS, OIL. G. Lieckfeld. *Lippincott, 1908.* 272 pp., 6 x 9¼, 306 figs. $4.50.

An English translation of a well-known German book. Deals with petroleum, benzol and alcohol engines. Properties of the fuels; historical development of the motors; construction of the parts; examples of modern construction, giving cost, weight, dimensions; applications for various purposes; erection and operation. The book is entirely descriptive, with no theory and but little explanation of functions of parts. A useful book in a limited field.

POWER, GAS. F. E. Junge. *Hill, 1908.* 548 pp., 6 x 9¼, 8 plates, 145 figs. *abdfA*. $5.

Part I: Evolution of gas power and economic aspects; includes a historical and critical study of the development of the present methods. Part II: Design and construction of large gas engines; with descriptions of the most prominent German types. Part III: Applications of gas power in iron and steel, coal-mining and coke-making industries, and elsewhere: use of low-grade fuels. A suggestive and useful treatment of the use of blast-furnace and coke-oven gases for developing large powers.

OTHER SOCIETIES

AMERICAN SOCIETY OF CIVIL ENGINEERS

At the meeting of the American Society of Civil Engineers on April 6, the New York tunnel extension of the Pennsylvania Railroad was discussed, with papers by B. F. Cresson, Jr., on The Terminal Station: West; and F. Lavis, on The Bergen Hill Tunnels. On April 20, Herbert M. Wilson presented a paper, entitled Federal Investigations of Mine Accidents, Structural Materials and Fuels, and the United States Testing Station at Pittsburg.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

The 246th meeting of the American Institute of Electrical Engineers was held in Charlotte, N. C., March 30 to April 1. Papers were presented by A. Milmow, on Electric Drive in Textile Mills; by E. D. Latta, Jr., on Gas Engines in City Railway and Light Service; by A. E. Kennelly, on Modifications of Hering's Laws of Furnace Electrodes; by Carl Hering, on The Proportioning of Electrodes for Furnace Electrodes; by E. E. F. Creighton on Some Demonstrations of Lightning Phenomena; by W. S. Lee, on Economics of Hydroelectric Plants; by L. C. Nicholson, on Protecting Insulators from Lightning and Power Arc Effects on the Lines of the Niagara and Lockport Power Co. Visits were made to various plants in the vicinity, including a tour of the Great Falls and Rocky Creek Stations and a 100,000-volt sub-station of the Southern Power Company.

Through the Industrial Power Committee the Institute coöperated with The American Society of Mechanical Engineers in the meeting of April 12, a report of which is given on an earlier page.

At the regular April monthly meeting, which was postponed to April 15, Dr. Samuel Sheldon, professor of physics and electrical engineering at Brooklyn Polytechnic Institute, presented a paper, Education for Leadership in Electrical Engineering, which was discussed by prominent educators.

Circumstances have made it expedient to change the date of the proposed meeting at San Francisco to May 5–7. This meeting is to be under the auspices of the High-Tension Transmission Committee. Arrangements are being made for tours of inspection to important standby plants and receiving stations, transmission plants and mountain generating stations, during that and the following week. The annual meeting of the Institute will be held in New York, May 17.

On May 27, there will be a special meeting, with papers, under the auspices of the Railway Committee. A list of papers for these meetings will be found in another department.

The annual convention wi l be held June 27-30 at Jefferson, N. H.

AËRO CLUB OF AMERICA

Headquarters have been opened in the Engineering Societies Building by the Aëro Club of America, and the public was invited to the opening meeting in the Auditorium of the building, Wednesday, April 13. A short address by Cortlandt F. Bishop, president of the club, was followed by an exhibit of moving pictures showing recent leading events in aërial navigation and the possibilities of aërial warfare. Views of the club's new aviation field at Mineola, L. I., including the sheds in which members may house their aëroplanes and several machines now under construction, were also thrown on the screen. Following these exercises, a reception was held in the rooms of the club.

NATIONAL METAL TRADES ASSOCIATION

The twelfth annual convention of the National Metal Trades Association was held at the Hotel Astor, New York, April 13, 14, 1910. On Wednesday, besides the routine reports, William Lodge, chairman of the committee on Industrial Education, offered a report reviewing the work of the Winona Technical Institute at Indianapolis, Ind., to the support of which the Association contributes. The papers presented were: Cincinnati's Continuation School, by Dr. Frank B. Dyer; Employers' Liability Insurance, by Miles Dawson; The Growth of the Coöperating System, by Prof. Herman Schneider; Insurance against Unemployment, by John L. Griffiths. The papers presented at the Thursday morning session were: Modern Methods of Shop Management, by Fred. S. Waldron, Mem.Am.Soc.M.E.; Premium Systems, by Carl G. Barth, Mem.Am.Soc.M.E.; Cincinnati's Continuation School, by J. Howard Renshaw. The annual banquet took place Wednesday evening at the Hotel Astor. President Wells presided as toastmaster, and the diners numbered about two hundred and fifty. J. H. Schwacke was elected president of the association.

ENGINEERS SOCIETY OF WESTERN PENNSYLVANIA

Notice has been received at this office of the removal April 27 of the Engineers Society of Western Pennsylvania to their new quarters in the Sixth Avenue wing, 25th floor, of the Oliver Building, Sixth Avenue and Smithfield Street, Pittsburg, Pa.

PERSONALS

John R. Allen, professor of machanical engineering, University of Michigan, will head the engineering school to be established at Robert College, Constantinople. Professor Allen will go to Turkey early next summer.

A biographical sketch of Prof. L. P. Breckenridge was published in the April issue of *Cassier's Magazine.*

Edward W. Burgess, formerly in the employ of the Metzger Motor Car Company, Detroit, Mich., has become connected with the J. I. Threshing Machine Company, Racine, Wis.

Gordon M. Campbell, formerly superintendent of the power apparatus shops of the Western Electric Co., Chicago, Ill., has become connected with the turbine department of the General Electric Co., West Lynn, Mass.

A. W. Cash, mechanical engineer and expert, recently located at Newark, N. J., has taken charge of the regulating valve and engineering department of the H. Mueller Mfg. Co., Decatur, Ill.

Walter Castanedo has been appointed manager for the New Orleans, La., district of the Harrisburg Foundry and Machine Works. He was formerly a member of the firm of Glenny & Castanedo, New Orleans, La.

S. M. Chandler has been appointed president of the Chandler-Boyd Supply Company, Pittsburg, Pa. He was formerly associated with the Pittsburg Valve and Fittings Company, Barberton, O.

Philip G. Darling, recently mechanical engineer of Manning, Maxwell & Moore, Inc., New York, has become associated with the development department of the E. I. du Pont de Nemours Powder Co., Wilmington, Del.

William W. Estes has accepted a position with the General Fire Extinguisher Company, Providence, R. I., as designer. Mr. Estes was until recently chief engineer of the R. I. Co., of the same city.

A. L. G. Fritz has become chief draftsman of the Hartford Suspension Company, Jersey City, N. J. Mr. Fritz was formerly associated with the Tee Square and Triangle Co., Newark, N. J.

Reuben Hill, formerly factory manager of the Bristol Engineering Corporation, Bristol, Conn., has entered the service of the Hudson Motor Car Company, Detroit, Mich.

Dr. D. S. Jacobus read a paper on Superheated Steam and Superheaters at the annual meeting of the National Association of Cotton Manufacturers, Boston, April 27, 28.

Charles Kirchhoff sailed for Europe April 19, expecting to be abroad for several months. He will sojourn for some time in Italy, and from there go to Germany.

Charles W. Lummis, recently mechanical engineer of the Camden Iron Works, Camden, N. J., has become identified with the Scovill Manufacturing Co., Waterbury, Conn.

Walter M. McFarland, who has occupied the office of acting vice-president for the Westinghouse Electric & Mfg. Co., Pittsburg, Pa., for a period extending over ten years, has resigned to accept an official position with the Babcock & Wilcox Co., Singer Building, New York.

D. H. Macdonald has entered the service of the Southern Engine and Boiler Works, Jackson, Tenn. He was formerly identified with the Minneapolis Steel and Machinery Company, Minneapolis, Minn., as general superintendent of the mechanical department.

John B. Mayo, formerly connected with the Crocker-Wheeler Co., Ampere, N. J., has been appointed mechanical engineer and chief draftsman of the Texas Portland Cement Company, Cement, Texas.

Fred J. Miller has been elected a member of the Board of Directors of the Union Typewriter Company.

Albert B. Moore, formerly chief engineer of the Griffin Wheel Company, Chicago, Ill., has resigned his position and formed a partnership with Andrew W. Woodman, under the firm name of Woodman & Moore, civil and mechanical engineers, with offices in the People's Gas Building, Chicago, Ill.

Francis P. Ritchie has accepted the position of factory manager of the Berliner Gramophone Company, Montreal, Canada. He was recently superintendent of the Northern Electric and Mfg. Co., of the same city.

William J. Sando, manager of the pumping engine and hydraulic turbine department of the Allis-Chalmers Co., for nearly six years, has resigned. After taking a few months' rest Mr. Sando will open an office in Boston as consulting engineer.

Walter G. Scott, recently associated with the Allis-Chalmers Co., West Allis, Wis., has become identified with the Cyclone Drill Company, Orville, O.

John J. Swan has become connected with the Keller Mfg. Co., of Philadelphia, Pa. Until recently he was secretary of the W. P. Pressinger Co., New York.

Charles E. Sweet, formerly superintendent of steam turbine construction, Westinghouse Machine Company, East Pittsburg, Pa., has become associated with the E. M. F. Co., Detroit, Mich.

Charles W. Werst has accepted a position with the Lima Locomotive and Machine Co., Lima, O., in the capacity of assistant superintendent. He was until recently general foreman of the Baldwin Locomotive Works, Philadelphia, Pa.

CURRENT BOOKS

American Machinists' Handbook and Dictionary of Shop Terms. A Reference Book of Machine Shop and Drawing Room Data, Methods and Definitions. By Fred H. Colvin and Frank A. Stanley. *New York: McGraw-Hill Book Co., 1909.* Morocco, pocket-book size, xxi +513 pp., illustrated. Price, $3.

Contents: Screw Threads: Cutting Screw Threads, Standard Proportions of Screw Threads, Measuring Screw Threads; Pipe and Pipe Threads; Twist Drills and Taps; Taps; Files; Work Benches; Soldering; Gearing; Milling and Milling Cutters; Cam Milling Machine Feeds and Speeds, Tables for Use with the Dividing Head, Milling Cutter, Reamer and Tap Flutes; Grinding and Lapping; Grinding Wheels and Grinding, Lapping, Reamer and Cutter Grinding; Screw Machine Tools, Speeds and Feeds: Types of Tools and their Construction, Speeds and Feeds for Screw Machine Work; Punch Press Tools; Bolts, Nuts and Screws: Tables of Cap and Machine Screw Dimensions, Tables of A. S. M.E. Standard Machine Screw Dimensions, Nut and Bolt Tables, Miscellaneous Tables; Calipering and Fitting: Press and Running Fits, Dimensions of Keys and Key-Seats; Tapers and Dovetails: Measuring Tapers, Tables of Standard Tapers; Shop and Drawing Room Standards: Standard Jig Parts, Tables of Dimensions of Standard Machine Parts, Miscellaneous Tables; Wire Gages and Stock Weights; Belts and Shafting; Steel and Other Metals; General Reference Tables; Shop Trigonometry; Dictionary of Shop Terms.

The American Practice of Gas Piping and Gas Lighting in Buildings. By Wm. Paul Gebhard. *New York, McGraw-Hill Book Co., 1908.* Cloth, 8vo, 306 pp. Price, $3.

Contents: Prejudices against the Use of Gas; Popular Fallacies about Gas; Advantages of Gas as an Illuminant; Advantages of Gas as a Source of Heat and Power; The Arrangement of Gas Piping in Buildings; Specification for Gas Piping for Coal or Water Gas; Rules, Tables and Regulations of Gas Companies and of Building Departments; Piping for Natural Gas; Piping for Air Gas or Gasolene Machine Gas; Piping for Acetylene Gas; The Testing of Gas Pipes; Gas-Light Illumination; Gas Burners; Gas-Pressure Regulation; Gas Globes and Globe Holders; Gas Fixtures; Gas Meters and Gas Meter Stories; The Illumination of Interiors with Gas Lights; The Lighting of Country Houses; The Relations between Gas Companies and Gas Consumers; Practical Hints for Gas Consumers; Some Facts about the Gas Supply; Accidents with Gas; Dangers to the Public Health from Illuminating and Fuel Gas; Historical Notes on the Development and Progress of the Gas Industry; Bibliography of Gas Lighting.

The Design and Construction of Oil Engines, with full directions for erecting, testing, installing, running and repairing; including descriptions of American and English kerosene oil engines. By A. H. Goldingham. 3d edition, revised and enlarged. *New York, Spon & Chamberlain, 1910.* Cloth, 12mo, viii+260 pp., illustrated. Price, $2.50.

Contents: Introductory; On Designing Oil Engines; Testing Engines; Cooling Water Tanks and Other Details; Oil Engines Driving Dynamos; Oil Engines Connected to Air Compressors, Water-Pumps, etc.; Instructions for Running Oil Engines; Repairs; Oil Engine Troubles; Various Engines Described; Portable Engines; Large Sized Engines; Fuels; Miscellaneous.

PRACTICE AND THEORY OF THE INJECTOR. By Strickland L. Kneass. 3d edition revised and enlarged. *New York, John Wiley & Sons, 1910.* Cloth, 8vo, 175 pp., illustrated. Price, $1.50.

Contents: Early History; Development of the Principle; Definition of Terms-Description of the Important Parts of the Injector; The Delivery Tube; The Combining Tube; The Steam Nozzle; The Action of the Injector; Application of the Injector—American and Foreign Practice; Determination of Size—Tests; Requirements of Modern Railroad Practice—Repairs—Methods of Feeding Locomotive Boilers; Feed Water Heating—Efficient Feeding—Flue Mileage—Scale-Bearing Water—Check Valves.

PUMPING ENGINES FOR WATER WORKS. By Charles Arthur Hague. *New York, McGraw-Hill Book Co., 1907.* Cloth, 8vo, xi + 372 pp., illustrated. Price, $5.

Contents: The Pumping Engine; Historical; Economic Steam Duty; The Advent of Triple Expansion; The Mariotte Curve; Steam Jackets; Coal Duty of Pumping Engines; Actual Conditions of Pumping; The Worthington Duplex Pumping Engine; The Gaskill Pumping Engine; The Reynolds Triple Expansion Pumping Engine; Various Types and Classes; Pumping Engines adapted to Conditions; Installation of Pumping Engines; Investment Value of Pumping Engines; Suction Lift and Suction Pipes; Water Passages and Water Valves; The Water Plungers; Air Chambers; Steam Piston; Steam Cylinders; Cross Heads; Frames and Bedplates; Material for Pumping Engines; Duty Tests of Pumping Engines.

DRAWINGS FOR MEDIUM SIZED REPETITION WORK. With Examples for Motor Car parts. By R. D. Spinney. *London, E. & F. N. Spon, Ltd., 1909.* Cloth 8 vo, + 91 pp., illustrated. Price. $1.50.

Contents: Drawings Generally; Standard Lists; Indexes; Tolerances; Dimensioning; Notes on Designing for Repetition Work; Drawing Office Routine.

ACCESSIONS TO THE LIBRARY

This list includes only accessions to the library of this Society, included in the Engineering Library. Lists of accessions to the libraries of the A.I.E.E. and A.I.M.E. can be secured on request from Calvin W. Rice, Secretary, Am.Soc.M.E.

American Machinists' Handbook and Dictionary of Shop Terms. By F. H. Colvin and F. A. Stanley. *New York, McGraw-Hill Book Company, 1909.*

American Practice of Gas Piping and Gas Lighting in Buildings. By W. P. Gerhard. *New York, McGraw-Hill Book Company, 1908.*

American Railway Association. Statistical bulletins Nos. 66, 67-B. *Chicago, 1910.*

The American Society of Mechanical Engineers. The Journal, vol. 31, Nos. 1-12. 2 vols. *New York, 1909.*

Ballistic Electro-Dynamometer Method of Measuring Hysteresis Loss in Iron. University of Kansas, Engineering Experiment Station, Bulletin No. 1. By M. E. Rice and Burton McCollum. *Lawrence, 1909.* (Gift.)

Briquetted Coal and its Value as a Railroad Fuel By C. T. Malcolmson.

Design and Construction of Oil Engines. Ed. 3. By A. H. Goldingham. *New York, Spon & Chamberlain, 1910.*

Design of Turbo Field Magnets for Alternate-Current Generators, with Special Reference to Large Units at High Speeds. By Miles Walker. Institution of Electrical Engineers, 1909. (Gift of Calvin W. Rice.)

Detroit Board of Water Commissioners. 57th annual report. *Detroit, 1909.* (Gift.)

Drawings for Medium-Sized Repetition Work. By R. D. Spinney. *New York, Spon & Chamberlain, 1909.*

Electric Railway and Lighting Properties. By Stone & Webster. *Boston, 1910.* (Gift of Calvin W. Rice.)

Epitome of the Work of the Aeronautic Society from July 1908 to December 1909. (Bulletin no. 1) *New York, 1909.* (Gift of Aeronautic Society, New York.)

Fifth Avenue Building Site of Fifth Ave. Hotel, Madison Square, New York. *New York.* (Gift of Fifth Avenue Building Company.)

Geology of the Auburn–Genoa Quadrangles. (New York State Museum, Bulletin no. 137.) By D. D. Luther. *Albany, 1910.* (Gift.)

Hawaii. Government and conditions before and since annexation to the United States and present requirements. Speech of Chauncey M. Depew, February 24, 1910. *Washington, 1910.* (Gift).

Innoko Gold-Placer District, Alaska. (Bulletin no. 410, U. S. Geological Survey.) By A. G. Maddren. *Washington, 1910.* (Gift.)

Iron Ores, Fuels and Fluxes of the Birmingham District, Alabama (Bulletin no. 400, U. S. Geological Survey.) By E. F. Burchard and Charles Butts. *Washington, 1910.* (Gift.)

Legal Aid Society. 24th annual report of the president, treasurer and attorneys. *New York, 1909.* (Gift.)

Locomotive Coaling Stations. (Bulletin no. 15, Roberts & Schaefer Co., Chicago.) *Chicago.* (Gift of author.)

Modern Coal Mining Plants and Washeries. (Bulletin no. 17, Roberts & Schaefer Co., Chicago.) *Chicago.* (Gift of author.)

Paleontology of the Coalinga District, Fresno and Kings Counties. California. (Bulletin no. 396, U. S. Geological Survey.) By Ralph Arnold. *Washington, 1909.* (Gift.)

Planning and Building of Industrial Plants. Section II. By Charles Day. *Dodge & Day. Philadelphia, 1909.*

Typical Operations. No. 2.

Possibilities of Electrical Power Transmission for Main Propulsions and Speed Regulation. By W. P. Durtnall. (Gift of author.)

Practice and Theory of the Injector. Ed. 3. By S. L. Kneass. *New York, J. Wiley & Sons, 1910.*

Progress of Electrical Braking on the Glasgow Corporation Tramway System. Institution of Electrical Engineers, 1910. By A. Gerrard. (Gift of Calvin W. Rice.)

Reconnaissance of some Mining Camps in Elko, Lander and Eureka Counties, Nevada. (Bulletin no. 408, U. S. Geological Survey.) By W. H. Emmons. *Washington, 1910.* (Gift.)

Results of Spirit-Leveling in Illinois, 1896 to 1908, inclusive. (Bulletin no. 421, U. S. Geological Survey.) *Washington, 1910.* (Gift.)

Short-Circuiting of Large Electric Generators and the Resulting Forces on Armature Windings. By Miles Walker. Institution of Electrical Engineers, 1909. (Gift of Calvin W. Rice.)

Tables of Efficiencies in Percentages, Butt and Double Strap Joints. Computed by W. W. Ramsay. *Boston 1910.* (Gift of Commonwealth of Massachusetts Board of Boiler Rules.)

Tests of Vertical Pumping at Quackenbush Pumping Station, Albany N. Y. *Chicago, 1909.* (Gift of H. A. Allen & Co.)

Trinity's Tenements. Condensed Report. *New York, 1909.* (Gift of Corporation of Trinity Church.)

EXCHANGES

American Gas Institute. Directory of Membership, 1909. *Easton, 1909.*

American Society of Civil Engineers. Constitution and List of Members, February 1910. *New York, 1910.*

American Society of Civil Engineers. Transactions, vol. 66. *New York, 1910.*

American Street and Interurban Railway Association. Membership list, 1910. *New York, 1910.*

Institution of Civil Engineers. Minutes of proceedings, vol. 179. *London, 1910.*

Institution of Engineers and Shipbuilders in Scotland. Transactions vol. 52. *Glasgow, 1909.*

Machinery Market. March 4, 1910-date *London, 1910-date.*

National Association of Cotton Manufacturers. Transactions, no. 87. *Boston, 1910.*

New York State Museum. 62d annual report, vol. 1, 1908. *Albany, 1909.*

Royal Society of New South Wales. Journal, vol. 42, 43, pt. 1. *Sydney, 1908-1909.*

Thermal Conductivity of Fire-Clay at High Temperatures. University of Illinois, Engineering Experiment Station, Bulletin no. 36. By J. K. Clement and W. L. Egy. *Urbana, 1909.*

UNITED ENGINEERING SOCIETY

International Who's Who, 1910–1911. *New York, International Who's Who Publishing Company, 1910.*

Designing and Detailing of Simple Steel Structures. By C. T. Morris. *Columbus, 1909.*

Gift of Schneider & Co.

Acier au Manganese, propriétés et applications. Extract from Le Génie Civil. *Paris, 1908.*

Acier au Manganese. *1909.*

Acier Speciaux pour Pièces d'Automobiles. Objets exposés. *Paris, 1906.*

Album des Fers et Aciers. *1895.*

Etablissements de MM. Schneider & Cie. *Nevers, 1900.*
Materiel automobile. *1909.*
Materiel Electrique à Courants Alternatifs. Alternateurs. *1909.*
——— Dynamos Schneider Type "*E*" 1909, type "*S*" 1909.
——— Moteurs triphases, 1905.
——— Transformateurs, 1907.

PRINCIPALES INSTALLATIONS COMPORTANT DES DYNAMOS "SCHNEIDER" A COURANT CONTINU. Liste des references, 1905.

ANNEXE NO 1. *1906-1907.*

PRINCIPALES INSTALLATIONS COMPORTANT DU MATERIAL ELECTRIQUE À COURANTS ALTERNATIFS DE NOTRE DERNIER TYPE. Liste des references, 1906.

ANNEXE NO. 1. *1907.*

TRAVAUX D'AMELIORATION DU PORT DU HAVRE. *Paris, 1907.*

TRADE CATALOGUES

AVERY SCALE COMPANY, *North Milwaukee, Wis.* Automatic coal weighing, 24 pp.
BLAKE & KNOWLES STEAM PUMP WORKS, *New York.* The Blake-Knowles open feed water heaters, 12 pp.

COMPAGNIE DES FORGES ET ACIÉRIES DE LA MARINE ET D'HOMECOURT. *France.* Iron and steel parts for automobiles for buildings, castings of all kinds, wheels, projectiles, guns, fire arms. *75pp.*

G. DROUVÉ CO., *Bridgeport, Conn.* The anti-pluvius puttyless skylight, and the Lovell window operator, 6 pp.

GENERAL ELECTRIC COMPANY, *Schenectady, N. Y.* Price list No. 5214: G. E. Edison, carbon incandescent lamps, 7 pp; No. 5218: G. E. trainlighting lamps, 3pp.; Mazda vs. Tungsten lamps, 6 pp.; Bulletin No. 4716: Thomson watt-hour meters with prepayment attachments for direct and alternating currents, 7 pp.; No. 4719, G. E. fan motors and small power motors, 36 pp.

GOLDSCHMIDT-THERMIT COMPANY, *New York.* Reactions—first quarter, a quarterly periodical devoted to the science of aluminothermics, 20 pp.

GREENE, KETCHUM & CO., *New York.* Sullivan smokeless furnace equipment, 16 pp.

H. G. HAMMETT, *Troy, N. Y.* Trojan metallic packing for locomotive piston rods and valve-stems, 8 pp.; Richardson locomotive valves, 15 pp.; Trojan bell ringer for locomotives, 2 pp.; Samson bell ringer for locomotives, 2 pp.; Link grinders, 2 pp.; Radias grinder, 2 pp.; Triple-valve bushing roller, 2 pp.

IRONWORKS COMPANY, *Jersey City, N. J.* Crowe mechanical stokers for stationary, marine or locomotive boilers, 36 pp.

Andrew J. Morse & Son, *Boston, Mass.* Illustrated catalogue of diving apparatus and other submarine appliances, 72 pp.

Nason Mfg. Co., *New York.* Nason "Vesuvius" steam trap, 8 pp.; Class B, Class C, and sidelug steam traps, 7 pp.

National Lock Washer Company, *Newark, N. J.* Catalogue of car curtains, curtain fixtures, sash locks, sash balances, nut locks, etc., 40 pp.

Nazel Engineering and Machine Works, *Philadelphia, Pa.* Béché patent pneumatic power hammer, 12 pp.

New Jersey Car Spring and Rubber Company, *Jersey City, N. J.* Rubber goods, as fire hose, packing, belts, mats, gaskets, etc., 132 pp.

New York Continental Jewel Filtration Co., *New York.* Mechanical filtration, water purification, filtration of public water supplies, 64 pp.

North Western Expanded Metal Co., *Chicago, Ill.* Expanded metal in use on highway bridges, 16 pp.; Designing data for the use of expanded metal and expanded metal lath, 70 pp.

Reagan Grate Bar Co., *Philadelphia, Pa.* Improved chopping grates for stationary boilers, 40 pp.; Improved chopping grates for marine and locomotive boilers, 28 pp.

Roberts Filter Mfg. Co., *Philadelphia, Pa.* Pressure water filters and filter appurtenances, 72 pp.; Improved water filter for domestic use, 12 pp.

Roberts & Schaefer Co., *Chicago.* Bulletin No. 17: Construction of coal-mining plants, coal-storage plants, mine-ventilating plants, in U. S., 116 pp.; Bulletin No. 15: Construction work of the railroad department, during 1905–1907, 75 pp.

Templeton Mfg. Co., *Boston, Mass.* Sterling steam trap, 7 pp.

Under-Feed Stoker Company of America, *Chicago.* Publicity Magazine, March 1910, devoted to the interests of the Jones stoker, 16 pp.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 15th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible posi ions. Information will be sent upon application.

POSITIONS AVAILABLE

022 Engineer experienced in the design and construction of single and multistage centrifugal and turbo-pumps. Must be thoroughly competent to make estimates and prepare complete calculations and data for drafting room. Location, Middle West.

023 Chief draftsman on hydraulic-turbine machinery and hydro-electric plants; one capable of handling draftsmen and pushing work through the drafting room in a systematic and economical manner. Location, Middle West.

024 Instructor in mechanical and architectural drawing, Tuesday and Thursday evenings, October to May. Drafting room practice and some experience in teaching necessary. Location, one hour from Manhattan.

025 Glass company, Western Pennsylvania, requires technical man for general engineering work covering testing of furnaces, boilers and producers; advice on purchase of materials and supplies; design and supervision of new construction. A good working knowledge of chemistry and several years experience in similar work desirable.

MEN AVAILABLE

58 Member, Cornell graduate; twelve years varied experience electrical construction, steam and electrical power-plant equipment, operation and repairs, ice-making and refrigeration engineering and construction; desires position as chief engineer or master mechanic of large industrial or ice and cold storage plant.

59 Member, fifteen years experience in design and construction; seven years teaching; now professor of Mechanical Engineering in the South, wants similar position in the North or Central West or with an established engineering concern.

60 Member, graduate in mechanical engineering with degrees of B.S. and M.E.; two years practical experience in machine design and construction; five years as instructor in mechanical engineering in State university; desires position as assistant professor of mechanical engineering or of machine design. Location immaterial.

61 Member of the Society, graduate engineer, age 57, fifteen years practical experience, drafting room, foundry and machine shop; selling machinery; desires position as general superintendent or manager, where interest in profitable business can be acquired. At present employed.

62 Associate member, age 33, five years practical experience in manufacturing, now head of mechanical engineering department of a Southern technical college, desires position for the summer months with some good manufacturing firm. Would prefer to act as representative in some part of the South, but will consider work of other kinds. Specially qualified along the lines of gas and steam engines and of refrigerating machinery.

63 Member, wants position as general superintendent or works manager; age 35, practical mechanic, technical education, good hustler and organizer; now superintendent of plant doing heaviest class of iron and steel work. At liberty June first, $5000 a year.

64 Junior, technical graduate, several years experience in shop, office, drafting room and testing, with unusual executive ability, force and adaptability, desires to make change.

65 Associate, technical graduate, two years mechanical and electrical draftsman, five years experience in teaching and engineering research, at present engaged in teaching, desires a change. Would like position as head of department of mechanical engineering in some small technical school offering possibilities of growth and development, or as professor or assistant professor of experimental engineering in some large college desiring to develop laboratory and research work. Salary expected $2200.

66 Responsible position in a prominent university desired by engineer; for the past nine years head of a college of Mechanical and Electrical Engineering. Good reasons for changing, record open for inspection.

67 Member, engineer graduate of U. S. Naval Academy, large and influential engineering acquaintance and broad experience in correspondence, selling, and manufacturing in large and well-known works, holding executive positions of responsibility, desires a position of trust with a good manufacturing concern, or responsible position on the commercial end of a business, as branch manager in Boston or elsewhere.

68 Member, chief draftsman in or near New York City. Experience in steam pumps, air compressors, condensers, Corliss engines.

69 Member, graduate M.E. and C.E., twenty-three years experience in general engineering, ten in hydroelectric developments. Charge of the design and installation of power plants in this and other countries; desires position, East preferred.

70 Member desires to communicate with concerns preferably in Pennsylvania, established in general powerplant engineering and contracting work, with a view of buying an interest and assuming an active part in the business; or taking an interest in some manufacturing concern building power-plant equipment or accessories.

71 Technical graduate, experienced in several varied lines of industry, holding executive positions of responsibility during the last eight or nine years, desires to become associated in position of trust with good manufacturing concern, preferably located in the East or Middle West. Best of references.

72 Sales manager, general manager or assistant with manufacturer of power plant apparatus, "water-tube" boiler manufacturer preferred; Junior member, age 32. References can be furnished that will be satisfactory to the most critical. Preferred location, Philadelphia or New York.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

BOCORSELSKI, F. E. (1907), Asst. Mech. Supt., Am. Loco. Co., and 1843 W. Grace St., Richmond, Va.

BRYAN, William H. (1891), Cons. Mech. and Elec. Engr., 315 and 316 Title Guaranty Bldg., and 5718 Vernon Ave., St. Louis, Mo.

BURGESS, Edward W. (Junior, 1908), J. I. Case Threshing Mch. Co., Racine, Wis.

BURGOON, Charles Eli (1907), Ch. Engr., U. S. Court House and P. O. Bldg., and 3824 Rokeby St., Chicago, Ill.

CARLE, Nathaniel A. (1907), Cons. and Contr. Engr., 510 Central Bldg., Seattle, Wash.

CARPENTER, Allan O. (Associate, 1909), Granville Center, Bradford Co., Pa.

CASTANEDO, Walter (1907; 1909), Dist. Mgr., Harrisburg Fdy. & Mch. Wks., 1103 Hennen Bldg., and *for mail*, 1514 Peters Ave., New Orleans, La.

CHANDLER, Sellers McKee (Junior, 1905), Pres., Chandler-Boyd Supply Co., Terminal Warehouses, and *for mail*, 741 Browne St., Shadyside, Pittsburg, Pa.

DARLING, Philip G. (Associate, 1906), Development Dept., E. I. du Pont de Nemours Powder Co., Wilmington, Del.

ENGLISH, Harry K. (Associate, 1908), Genl. Elec. Co., Monadnock Bldg., Chicago, Ill.

FRITZ, Aime L. G. (Junior, 1907), Ch. Draftsman, Hartford Suspension Co., 150 Bay St., Jersey City, N. J.

GERRISH, William H. (1901), 15 Gould Ave., Malden, Mass.

GORDON, Frederic W. (1880), Clardon, Orchard Lane, Ft. Washington, Pa.

GUMP, Walter B. (Junior, 1902), Mech. and Elec. Engr., 206 Kerckhoff Bldg., Los Angeles, Cal.

HAGY, J. L. (Junior, 1901), Harrison Safety Boiler Wks., Tioga, and *for mail*, 1525 Montgomery Ave., Philadelphia, Pa.

HENES, Harry Wm. (Junior, 1909), 557 Barry Ave., Chicago, Ill.

HENSHAW, Frederick V. (1900), Cons. Engr., 24 Broad St., New York, and 79 State St., Brooklyn, N. Y.

HILL, Reuben (1908), Hudson Motor Car Co., Detroit, Mich.

JONES, Charles E. (1894), Mech. Engr., Instr. in Forging, Manual Training Sch. of Washington Univ., 5361 Von Verson Ave., St. Louis, Mo.

KEAN A. J. A. (1908), Ch. Operating Engr., Guanajuato Power & Elec. Co., Apartado 50, Guanajuato, Mexico.

KENYON, Alfred Lewis (1904), care Dr. A. C. Griggs, Warrensburg, Mo.

KREUTZBERG, Otto August (Associate, 1904), V. P., Pfannmueller Engrg. Co., 3701 S. Ashland Ave., and 38 Roslyn Pl., Chicago, Ill.

LAMBIE, James M. (Junior, 1908), Asst. Genl. Mgr., Findlay Clay Pot Co., Findlay, O., and *for mail*, 306 E. Maiden St., Washington, Pa.

LUCAS, Henry M. (1904), Lucas Mch. Tool Co., E. 99th St. and L. S. & M. S. R. R., Cleveland, and *for mail*, 82 Page Ave., East Cleveland, O.

LUMMIS, Charles W. (Associate, 1907), Scovill Mfg. Co., Waterbury, Conn.

MACDONALD, Duncan H. (1903), Southern Eng. & Boiler Wks., Jackson, Tenn.

MASON, William (1880), 78 Burncoat St., Worcester, Mass.

MAYO, John B. (1892;1894), Mech. Engr. and Ch. Draftsman, Texas Portland Cement Co., Cement, Tex.

MERRITT, Joseph (1907), Cons. and Constr. Mech. Engr., 60 Prospect St., and 64 Deerfield Ave., Hartford, Conn.

MOORE, Albert B. (1903), Member of Firm, Woodman & Moore, Civ. and Mech. Engrs., Peoples Gas Bldg., and *for mail*, 5426 Jefferson Ave., Chicago, Ill.

NORRIS, William H., Jr. (Junior, 1909), Engr., W. R. Grace & Co., Lima, Peru.

OLIVER, E. C. (Junior, 1902), 475 Second Ave., Detroit, Mich.

OWEN, Ira June (Junior, 1905), Cons. Engr., Rm. 502, 115 Dearborn St., Chicago, and 110 Maple Ave., Oak Park, Ill.

PARK, Walter E. (1903), Young & Park, 45 Broadway, New York, N. Y.

PITKIN, Joseph Lovell (Associate, 1903), 72 Washington St., Atlanta, Ga.

PRESSINGER, W. P. (Associate, 1903), V. P. and Mgr. of Sales, Keller Mfg. Co., 21st St. and Allegheny Ave., Philadelphia, Pa.

RIGDON, Carl (Junior, 1907), 710 Market St., Chattanooga, Tenn.

RITCHIE, Francis P. (Associate, 1908), Factory Mgr., Berliner Gramophone Co., and *for mail*, 32 Sussex Ave., Montreal, Canada.

ROGERS, Charles Edward (Associate, 1898), Genl. Mgr., Fraser & Chalmers. Ltd., Corner House, and The Pines, Gordon Hill Rd., Parktown, Johannesburg, South Africa.

ROGERS, Robert W. (Junior, 1908), Mech. Engr., C. A. Stickney Co., and *for mail*, The Meadows, Dodd Pl., St. Paul, Minn.

RYDER, Malcolm P. (Associate, 1901), Engr., Witherbee Igniter Co., Springfield, Mass., and 11 Warren St., White Plains, N. Y.

SHALLENBERGER, Louis R. (1895; 1902), Box 55, Fenton, Mich.

STIMSON, Oscar M. (1906), O. M. Stimson & Co., First Natl. Bank Bldg., Chicago, Ill.

STREET, Clement F. (1893), with firm of Clement F. Street, Locomotive Stokers, 1427 Schofield Bldg., Cleveland, O.

SWAN, John Joseph (1899; 1909), Keller Mfg. Co., 21st and Lippincott Sts., Philadelphia, Pa., and Plainfield, N. J.

SWEET, Charles E. (1907), E. M. F. Co., Detroit, Mich.

SWENSON, Bernard Victor (1903), Barron G. Collier, Inc., 175 Fifth Ave., New York, N. Y.

THOMAS, Fred H. (Junior, 1909), Sales Engr., C. & G. Cooper Co., Mt. Vernon, O.

WALKER, Frank A. (Junior, 1909), with B. B. & R. Knight, and *for mail*, 46 Ring St., Providence, R. I.

WERST, Chas. Wm. (1909), Asst. Supt., Lima Loco. & Mch. Co., and *for mail*, 1160 W. High St., Lima, O.

WILLIAMS, Alan Gillespie (Junior, 1909), 112 Central Ave., South Oil City, **Pa.**
WOODS, Samuel Hamilton (Junior, 1907), Richardson & Boynton Co., 31 W. 31st St., and 73 W. 12th St., New York, N. Y.
YOUNG, William A. (1901; 1905; 1906), Ch. Draftsman, Morgan Engrg. Co., and *for mail*, 522 S. Arch St., Alliance, O.

NEW MEMBERS

ARNOTT, R. Fleming (Associate, 1909), Cons. Engr., 95-97 Liberty St., New York, N. Y.
BECK, Rudolph H. (Junior, 1909), United Iron Works, Seattle, Wash.
BONNEY, Herbert Marshall (Junior, 1909), Ch. Draftsman, L. F. Fales, and *for mail*, Walpole, Mass.
NELSON, Eric Hugo (1909), Ch. Draftsman, Geo. F. Blake Mfg. Co., Cambridge, and *for mail*, 61 Leverett Ave., Beachmont, Mass.

DEATHS

BLESSING, James H., February 21, 1910.
BRIDGE, James W., December 20, 1909.
CHURCHILL, William W., March 25, 1910.
HASKINS, Harry S., March 13, 1910.
REDWOOD, Iltyd I., April 5, 1910.
SIMS, Gardiner C., March 19, 1910.
SIRICH, J. Henry, Jr., January 22, 1910.

GAS POWER SECTION

CHANGES OF ADDRESS

ENGLISH, Harry K. (1909), Mem. Am. Soc. M. E.

FISKE, Geo. Wallace (Affiliate, 1909), 816 Huntoon St., Topeka, Kan.

HOPCROFT, Ernest Bigly (Affiliate, 1908), present address unknown.

LATHROP, Jay Cowden (Affiliate, 1908), Supt. of Constr., Peoples Ry. Co., Dayton, O.

LUMMIS, Charles W. (1908), Mem. Am. Soc. M. E.

MANGELSDORFF, Max F. (Affiliate, 1910), 115 Nassau St., New York, N. Y., and *for mail*, 212 Fifth St., Union Hill, N. J.

QUINN, Stephen (Affiliate, 1909), Ch. Engr., Iola Portland Cement Co., and *for mail* Clinker Club, 16 N. Buckeye St., Iola, Kan.

ROTH, Charles (Affiliate, 1909), Mech. Engr., L. A. Becker Co., Chicago, and *for mail*, 220 Marion St., Oak Park, Ill.

THOMPSON, Wm. K. (Affiliate, 1909), 2619 Orchard Ave., Los Angeles, Cal.

NEW MEMBERS

JAMES, Frederick Conway (Affiliate, 1910), Cons. Engr., Mangold Bros., Port Elizabeth, and *for mail*, Steytlerville, Cape Colony, South Africa.

STUDENT BRANCHES

CHANGES OF ADDRESS

BINNS, G. W. (Student, 1910), 2358 Ohio Ave., Cincinnati, O.
FRAMBACH, F. S. (Student, 1910), Hartley Hall, Columbia Univ., New York, N. Y.
HAINES, P. G. (Student, 1910), 3153 Willis Ave., Cincinnati, O.
HENWOOD, P. E. (Student, 1909), 4620 Calumet Ave., Chicago, Ill.
HOLLENBERGER, Theo. J. (Student, 1909), 4433 N. Paulina St , Chicago, Ill.
KARMAZIN, John (Student, 1910), 1001 S. 5th St., Champaign, Ill.
LURIE, A. N. (Student, 1909), 1871 S. Kedzie Ave., Chicago, Ill.
MARSH, Karl H. (Student, 1910), with Arthur G. McKee, Engr., Rockefeller Bldg., Cleveland, O.
MURDUCK, R. K. (Student, 1910), 705 W. Hill St., Champaign, Ill.
YOAKUM, F. E., Jr. (Student, 1909), 201 Dryden Rd., Ithaca, N. Y.

NEW MEMBERS

BROOKLYN POLYTECHNIC INSTITUTE

BREVOORT, C. (Student, 1910), 69 Lincoln Rd., Flatbush, N. Y.

COLUMBIA UNIVERSITY

DAVIS, F. R. (Student, 1910), 220 W. 107th St., New York, N. Y.
DEMOREST, W. J. (Student, 1910), 173 W. 93d St., New York, N. Y.
SWALLOW, Howard (Student, 1910), 605 W. 184th St., New York, N. Y.
VAUGHAN, L. L. (Student, 1910), Hartley Hall, Columbia Univ., New York, N. Y.
VON MAHLENBORG, C. A. (Student, 1910), 127 W. 111th St., New York, N. Y.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

ESTES, G. H. (Student, 1910), 31 Newbury St., Boston, Mass.
MACKENZIE, Morril (Student, 1910), 68 Barnum St., Taunton, Mass.
ROBB, Charles A. (Student, 1910), 12 Oxford St., Cambridge, Mass.
RUSSELL, Foster (Student, 1910), 80 St. Botolph St., Boston, Mass.
STONE, R. T. (Student, 1910), Tech. Chambers, Boston, Mass.

UNIVERSITY OF CINCINNATI

COLBURN, B. V. (Student, 1910), 2343 Stratford Ave., Cincinnati, O.
HUMPHREYS, H. B. (Student, 1910), 236 Ofallon Ave., Bellevue, Ky.
LYTLE, C. W. (Student, 1910), 2345 Stratford Ave., Cincinnati, O.

UNIVERSITY OF ILLINOIS

CARLSON, C. A. (Student, 1910), 1015 W. Illinois St., Urbana, Ill.
JACOBSEN, C. H. (Student, 1910), 906 W. Illinois St., Urbana, Ill.
LINDSTROM, A. W (Student, 1910), 307 E. Daniel St., Champaign, Ill.
PAUL, Harry (Student, 1910), 209 E. Green St., Champaign, Ill.

COMING MEETINGS

May–June

Advance notices of annual and semi-annual meetings of engineering societies are regularly published under this heading and secretaries or members of societies whose meetings are of interest to engineers are invited to send such notices for publication. They should be in the editor's hands by the 18th of the month preceding the meeting. When the titles of papers read at monthly meetings are furnished they will also be published.

AIR BRAKE ASSOCIATION

May 10–13, Dennisson Hotel, Indianapolis, Ind. Subjects for discussion. and chairmen: Air Brake Instruction, Examination and Rating, Thos. Clegg; Air Pump Piping, Fittings and Connections, George W. Kiehm; Best Arrangement of Air Pump and Main Reservoir Capacity for 100-car Train Service, P. J. Langan; Brake Cylinders and Connections to Cylinder Leakage, W. P. Garabrant; Inspection and Cleaning of Triple Valves and Brake Cylinders, C. P. McGinnis; Developments in Air Brakes, W. V. Turner; New York Brake Equipment, T. F. Lyons; Westinghouse Equipment, S. G. Down; Recommended Practice, S. G. Down. Secy., F. M. Nellis, 53 State St., Boston, Mass.

AMERICAN ASSOCIATION ELECTRIC MOTOR MANUFACTURERS

May 18, Newport News, Va. Secy., Frank H. Couch, Hampton.

AMERICAN CIVIC ALLIANCE

May 18, 29 W. 39th St., New York. Secy., Henry Frank.

AMERICAN EXPOSITION IN BERLIN

June 1-Aug. 31. American Manager, Max Vieweger, 50 Church St., New York.

AMERICAN FOUNDRYMEN'S ASSOCIATION
MANUFACTURERS SUPPLY ASSOCIATION

June 6–10, Detroit, Mich. Secy. of general committee, A. Preston Henry, Standard Pattern Works.

AMERICAN ELECTROCHEMICAL SOCIETY

May 4–7, Spring Meeting, Fort Pitt Hotel, Pittsburg, Pa. Among the papers will be: Furnace Conductors for Heavy Alternating Currents, K. C. Randall; A New Electric Steel Furnace, A. L. Queneau; Gases in Steel, P. L. T. Heroult; Cheap Power in the Pittsburg District, F. Crabtree; Induction Furnace Progress, T. Rowlands; Ductile Tungsten and Molybdenum, C. G. Fink; A New Process for the Treating of Cobalt-nickel Ores, C. C. Cito; A New Radiation Pyrometer, C. E. Foster, Mem. Am. Soc. M.E.; The Separation of Oil from Condenser Water by Electrolysis, H. M. Goodwin; A New Method for the Electrolytic Winning and Refining of Metals, E. M. Chance; Refining of Tin Dross in an Electric Furnace, R. S. Wile; The Effect of Moisture and of Solutions upon the Electrical

Conductivity of Soils, R. E. O. Davis; The Present Status of the Electro-Chemical Industries, J. W. Richards; Pittsburg as an Electrochemical Center, John A. Brashear, Mem.Am.Soc.M.E.; The Conservation and Utilization of Natural Sources of Power, J. H. Finney.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

June 22-24, summer meeting, Niagara Falls, N. Y. Secy., J. C. Olsen, Polytechnic Inst., Brooklyn.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

May 5-7, Auditorium of Home Telephone Co., 333 Grant Ave., San Francisco, Cal. Papers: Emergency Generating Stations for Service in Connection with Hydroelectric Transmission Plants under Pacific Coast Conditions, A. M. Hunt, Mem. Am. Soc. M. E.; Hydroelectric Power as Applied to Irrigation, J. C. Hays; The Developed High-Tension Net-Work of a General Power System, Paul M. Downing; Parallel Operation of Three-Phase Generators with their Neutrals Interconnected, G. I. Rhodes; Observations of Harmonics in Current and Potential Wave Shapes of Transformers, John J. Frank; Transmission Line Crossings of Railroad Right-of-way, A. H. Babcock. May 17, Annual Meeting; 33 W. 39th St., New York. May 27, special railway meeting, 33 W. 39th St. Papers: Application of Porcelain to Strain Insulators, W. H. Kempton; Electric Railway Overhead Construction, W. N. Smith. June 27-28, Annual Convention, Waumbeck Hotel, Jefferson, N. H. Secy., R. W. Pope, 33 W. 39th St.

AMERICAN PORTLAND CEMENT MANUFACTURERS

June, Kansas City, Kan. Secy., P. H. Wilson, Land Title Bldg., Philadelphia, Pa.

AMERICAN RAILWAY ACCOUNTING OFFICERS

June 29, Colorado Springs, Colo. Secy., C. G. Phillips, 143 Dearborn St., Chicago.

AMERICAN RAILWAY ASSOCIATION

May 18, 29 W. 39th St. New York, 11 a.m. Secy, W. F. Allen, 24 Park Pl.

AMERICAN RAILWAY INDUSTRIAL ASSOCIATION

May 10, Memphis, Tenn. Secy., Guy L. Stewart, S. W. Ry., St. Louis, Mo.

AMERICAN RAILWAY MASTER MECHANICS ASSOCIATION

June 20-22, Atlantic City, N. J. Secy., J. W. Taylor, 390 Old Colony Bldg., Chicago.

AMERICAN SOCIETY OF CIVIL ENGINEERS

May 4, 18, 220 W. 57th St., New York. Papers, May 4: Water Supply of El Paso & Southwestern Railway from Carrizozo to Santa Rosa, New Mexico, J. L. Campbell; New York Tunnel Extension of Pennsylvania Railroad: Site of the Terminal Station, G. C. Clarke. Secy., C. W. Hunt.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

May 14, St. Louis, with coöperation of Engineers Club of St. Louis. May 31-June 3, Spring Meeting, Atlantic City, N. J. July 26-29, meeting with Institution of Mechanical Engineers, in Birmingham and London, England. Secy., Calvin W. Rice, 29 W. 39th St., New York.

AMERICAN SOCIETY FOR TESTING MATERIALS

June 28-July 2, annual meeting, Atlantic City, N. J. Secy., Edgar Marburg, University of Pennsylvania, Philadelphia.

ASSOCIATION OF CAR-LIGHTING ENGINEERS

June 7, 8, semi-annual convention, Buffalo, N. Y. Secy., Geo. B. Colegrave, care of Central Railway, Chicago.

BROOKLYN ENGINEERS CLUB

May 5, clubhouse, 117 Remsen St., 8 p.m. Paper: Steel Centering as Applied to the Catskill Aqueduct, V. R. Whitehall. May 14, visit to Pa. R. R. Sta., New York. Secy., Joseph Strachan.

CANADIAN GAS ASSOCIATION

June 9-11, annual convention, Alexander Rink, Hamilton, Ont. Secy., A. W. Moore, Woodstock, Ont.

CENTRAL RAILWAY CLUB

May 13, Buffalo, N. Y Secy., H. D. Vought, 95 Liberty St., New York.

CLEVELAND ENGINEERING SOCIETY

June 14, annual meeting, 714 Caxton Bldg. Secy., J. C. Beardsley.

ENGINEERS' CLUB OF BALTIMORE

June 4, annual meeting. Secy., R. K. Compton, City Hall.

ENGINEERS SOCIETY OF MILWAUKEE

June 8, annual meeting, Builders Club. Secy., W. F. Martin, 456 Broadway.

ENGINEERS SOCIETY OF PENNSYLVANIA

June 7, annual meeting, Gilbert Bldg., Harrisburg. Secy., E. R. Dasher, P. O. Box 704.

ENGINEERS' CLUB OF ST. LOUIS

May 14, coöperating with Am. Soc. M. E. Secy., A. S. Landsdorf, 3817 Olive St.

FOUNDRY AND MANUFACTURERS' SUPPLY ASSOCIATION

June 6-10, Detroit, Mich. Secy., C. E. Hoyt, Lewis Institute, Chicago.

FREIGHT CLAIM ASSOCIATION

June 15, Los Angeles, Cal. Secy., W. P. Taylor, Richmond, Va.

INTERNATIONAL CONGRESS OF INVENTORS

June 13-18, Rochester, N. Y.

INTERNATIONAL CONGRESS OF MINING, METALLURGY, APPLIED MECHANICS AND PRACTICAL GEOLOGY

Last week in June, Düsseldorf, Prussia. Secy., Dr. E. Schrödter, Jacobstrasse 315.

INTERNATIONAL MASTER BOILER MAKERS' ASSOCIATION

May 24-26, New Clifton Hotel, Niagara Falls, Ont. Subjects for discussion and chairmen: Standardizing of Blue Prints, W. H. Laughridge; Application and Care of Flues, D. A. Lucas; Flexible Staybolts, C. J. Murray; Steel vs. Iron Tubes, M. O'Connor; Flue Holes in Back Flue Sheet, J. A. Dearnberger; Standardizing of Shop Tools, J. T. Goodwin; Standardizing of Pipe Flanges and Templates for Drilling, Jas. Crombie; Radical Departures in Boilers and Fire Boxes, B. F. Sarver; Fire Box Holes, W. H. Laughridge; Best Method of Staying Front Portion of Crown Sheet on Radical Top Boilers to prevent Cracking of Flue Sheet in Top Flange, H. J. Raps; Oxy-Acetylene Welding, M. O'Connor. Secy., H. D. Vought, 95 Liberty St., New York.

INTERNATIONAL RAILWAY FUEL ASSOCIATION

May 23-26, Chicago. Secy., D. B. Sebastian, 327 LaSalle St. Sta.

INTERNATIONAL RAILWAY GENERAL FOREMEN'S ASSOCIATION
May 3-7, Cincinnati, O. Secy., E. C. Cooke, Royal Ins. Bldg., Chicago.

IOWA DISTRICT GAS ASSOCIATION
June 15-17, annual meeting, Sioux City. Secy., G. I. Vincent, Des Moines.

LOUISIANA ENGINEERING SOCIETY
May 9, June 13, 321 Hibernia Bldg., New Orleans. Papers: The Manufacture of Sugar, W. H. P. Creighton; Coal in Relation to Boiler Economy, Wm. von Phul. Secy., L. C. Datz.

MASTER CAR BUILDERS ASSOCIATION
June 15-17, Atlantic City, N. J. Secy., J. W. Taylor, 390 Old Colony Bldg., Chicago.

MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK
May 27, inspection trip to Albany and Schenectady. Secy., C. D. Pollock, 29 W. 39th St., New York.

NATIONAL ASSOCIATION OF MANUFACTURERS
May 16-18, New York. Secy., George S. Boudinot, 170 Broadway.

NATIONAL DISTRICT HEATING ASSOCIATION
June 1-3, annual meeting, Toledo, O. Secy., D. C. Gaskill, Greenville, O.

NATIONAL ELECTRIC LIGHT ASSOCIATION
May 23-28, St. Louis, Mo., Secy., Frank H. Tate, Dayton, O.

NATIONAL ELECTRIC TRADES ASSOCIATION
June, San Francisco, Cal. Secy., F. B. Vose, 1343 Marquette Bldg., Chicago

NATIONAL FIRE PROTECTION ASSOCIATION
May 17-19, annual meeting, Hotel LaSalle, Chicago. Address by I. K. Pond, Pres. Am. Inst. Architects, etc. Secy., F. H. Wentworth, 87 Milk St., Boston.

NATIONAL GAS AND GASOLENE ENGINE TRADES ASSOCIATION
June 13-16, Semi-annual convention, Hotel Sinton, Cincinnati, O. Secy., Albert Stritmatter.

NATIONAL MACHINE TOOL-BUILDERS ASSOCIATION
May 24, 25, Spring Convention, Hotel Seneca, Rochester, N. Y. Secy., C. E. Hildreth, Worcester, Mass.

NATURAL GAS ASSOCIATION OF AMERICA
May 17-19, Oklahoma City, Okla. Secy., M. W. Walsh, 110 N. Broadway.

NEW ENGLAND WATERWORKS ASSOCIATION
June, Providence, R.I. September 14-16, annual convention, Rochester, N. Y. Secy., Willard Kent, Narragansett Pier, R. I.

NEW YORK RAILROAD CLUB
May 20, 29 W. 39th St., 8.15 p.m. Secy., H. D. Vought, 95 Liberty St.

OHIO SOCIETY OF ENGINEERS
May 19, 20, Cincinnati. Secy., F. E. Sanborn, State University, Columbus.

PROVIDENCE ASSOCIATION OF MECHANICAL ENGINEERS
May 24, West Hall, R. I. School of Design, 8 p. m. Paper: Modern Machine Tools. Second week in May, Spring visitation, The Norton Co., Worcester, Mass., June 28, annual meeting. Secy., T. M. Phetteplace, Mem. Am.Soc.M.E., 48 Snow St.

RAILWAY SIGNAL ASSOCIATION
June 14, 29 W. 39th St., New York, 9.30 a.m. Secy., C. C. Rosenberg, Bethlehem, Pa.

RENSSELAER SOCIETY OF ENGINEERS

June, annual meeting, Rensselaer Polytechnic Inst., 257 Broadway, Troy, N. Y. Secy., R. S. Furber.

ST. LOUIS RAILWAY CLUB

May 13. Secy., B. W. Frauenthal, Union Station.

SOCIETY FOR PROMOTION OF ENGINEERING EDUCATION

June 23–25, Madison, Wis. Papers on Technical Education Abroad, Inspection Trips for Technical Students. Efficiency in Technical Education. Secy., H. H. Norris, Cornell University, Ithaca. N. Y.

STEVENS ENGINEERING SOCIETY

May 3, 10, Hoboken, N. J. Papers by C. F. Kroeh and J. A. Brashear, Hon. Mem.Am.Soc.M.E.

TELEPHONE SOCIETY OF NEW YORK

June 21, annual meeting, 29 W. 39th St. Secy., T. H. Woolhouse.

TRANSPORTATION AND CAR ACCOUNTING OFFICERS

June 28. Secy., G. P. Conard, 24 Park Pl., New York.

WESTERN CANADA RAILWAY CLUB

May 9, annual meeting, Royal Arms Hotel, Winnipeg, Manitoba. Secy., W. H. Rosevear, P. O. Box 1707.

MEETINGS IN THE ENGINEERING SOCIETIES BUILDING

Date	Society	Secretary	Time
May			p. m.
4	Wireless Institute	S. L. Williams	7.30
5	Blue Room Engineering Society	W. D. Sprague	8.00
6	Western Union Electrical Society	H. C. Northen	7.00
7	Amer. Soc. Hungarian Engrs. and Archts	Z. deNemeth	8.30
12	Illuminating Engineering Society	P. S. Millar	8.00
13	Western Union Electrical Society	H. C. Northen	7.00
17	American Institute of Electrical Engineers	R. W. Pope	8.00
17	New York Telephone Society	T. H. Lawrence	8.00
			a. m.
18	American Railway Association	W. F. Allen	11.00
			p. m.
18	American Civic Alliance	Henry Frank	2.30 8.00
20	New York Railroad Club	H. D. Vought	8.15
20	Western Union Electrical Society	H. C. Northen	7.00
25	Municipal Engineers of the City of New York	C. D. Pollock	8.15
27	American Institute of Electrical Engineers	R. W. Pope	8.00
27	Western Union Electrical Society	H. C. Northen	7.00
June			
1	Wireless Institute	S. L. Williams	7.30
2	Blue Room Engineering Society	W. D. Sprague	8.00
3	Western Union Electrical Society	H. C. Northen	7.00
4	Amer. Soc. Hun. Engrs. and Archts	Z. deNemeth	8.30
9	Illuminating Engineering Society	P. S. Millar	8.15
10	Western Union Electrical Society	H. C. Northen	7.00

Date	Society	Secretary	Time
June			a.m.
14	Railway Signal Association	C. C. Rosenberg	9 30
			p. m.
17	Western Union Electrical Society	H. C. Northen	7 00
21	New York Telephone Society	T. H. Lawrence	8 00
24	Western Union Electrical Society	H. C. Northen	7 00

OFFICERS AND COUNCIL

PRESIDENT

George Westinghouse .... Pittsburg, Pa.

VICE-PRESIDENTS

Geo. M. Bond .... Hartford, Conn.
R. C. Carpenter .... Ithaca, N. Y.
F. M. Whyte .... New York

Terms expire at Annual Meeting of 1910

Charles Whiting Baker .... New York
W. F. M. Goss .... Urbana, Ill.
E. D. Meier .... New York

Terms expire at Annual Meeting of 1911

PAST PRESIDENTS

Members of the Council for 1910

John R. Freeman .... Providence, R. I.
Frederick W. Taylor .... Philadelphia, Pa.
F. R. Hutton .... New York
M. L. Holman .... St. Louis, Mo.
Jesse M. Smith .... New York

MANAGERS

Wm. L. Abbott .... Chicago, Ill.
Alex. C. Humphreys .... New York
Henry G. Stott .... New York

Terms expire at Annual Meeting of 1910

H. L. Gantt .... Pawtucket, R. I.
I. E. Moultrop .... Boston, Mass.
W. J. Sando .... Milwaukee, Wis.

Terms expire at Annual Meeting of 1911

J. Sellers Bancroft .... Philadelphia, Pa.
James Hartness .... Springfield, Vt.
H. G. Reist .... Schenectady, N. Y.

Terms expire at Annual Meeting of 1912

TREASURER

William H. Wiley .... New York

CHAIRMAN OF THE FINANCE COMMITTEE

Arthur M. Waitt .... New York

HONORARY SECRETARY

F. R. Hutton .... New York

SECRETARY

Calvin W. Rice .... 29 West 39th Street, New York

EXECUTIVE COMMITTEE OF THE COUNCIL

Alex. C. Humphreys, *Chairman*
Chas. Whiting Baker, *Vice-Chairman*
F. R. Hutton
H. L. Gantt
F. M. Whyte

STANDING COMMITTEES

FINANCE

Arthur M. Waitt (5), *Chairman*
Robert M. Dixon (3), *Vice-Chairman*
Edward F. Schnuck (1)
Geo. J. Roberts (2)
Waldo H. Marshall (4)

HOUSE

William Carter Dickerman (1) *Chairman*
Francis Blossom (3)
Bernard V. Swenson (2)
Edward Van Winkle (4)
H. R. Cobleigh (5)

LIBRARY

John W. Lieb, Jr. (3), *Chairman*
Leonard Waldo (2)
Ambrose Swasey (1)
Chas. L. Clarke (4)
Alfred Noble (5)

MEETINGS

Willis E. Hall (5), *Chairman*
L. R. Pomeroy (2)
Wm. H. Bryan (1)
Chas. E. Lucke (3)
H. de B. Parsons (4)

MEMBERSHIP

Charles R. Richards (1) *Chairman*
George J. Foran (3)
Francis H. Stillman (2)
Hosea Webster (4)
Theo. Stebbins (5)

PUBLICATION

D. S. Jacobus (1) *Chairman*
H. W. Spangler (3)
H. F. J. Porter (2)
Geo. I. Rockwood (4)
Geo. M. Basford (5)

RESEARCH

W. F. M. Goss (4), *Chairman*
R. H. Rice (2)
R. C. Carpenter (1)
Ralph D. Mershon (3)
Jas. Christie (5)

Note—Numbers in parentheses indicate number of years the member is yet to serve.

SPECIAL COMMITTEES

1910

On a Standard Tonnage Basis for Refrigeration

D. S. Jacobus
A. P. Trautwein
G. T. Voorhees
Philip De C. Ball
E. F. Miller

On Society History

John E. Sweet
H. H Suplee
Chas. Wallace Hunt

On Constitution and By-Laws

Chas. Wallace Hunt, *Chairman*
G. M. Basford
F. R. Hutton
D. S. Jacobus
Jesse M. Smith

On Conservation of Natural Resources

Geo. F. Swain, *Chairman*
Charles Whiting Baker
L. D. Burlingame
M. L. Holman
Calvin W. Rice

On International Standard for Pipe Threads

E. M. Herr, *Chairman*
William J. Baldwin
Geo. M. Bond
Stanley G. Flagg, Jr.

On Standards for Involute Gears

Wilfred Lewis, *Chairman*
Hugo Bilgram
E. R. Fellows
C. R. Gabriel
Gaetano Lanza

On Power Tests

D. S. Jacobus, *Chairman*
Edward T. Adams
George H. Barrus
L. P. Breckenridge
William Kent
Charles E. Lucke
Edward F. Miller
Arthur West
Albert C. Wood

On Student Branches

F. R. Hutton, Honorary Secretary

On Meetings of the Society in Boston

Ira N. Hollis, *Chairman*
Edward F. Miller
I. E. Moultrop, *Secretary*
J. H. Libbey
Charles T. Main

On Meetings of the Society in St. Louis

Wm. H. Bryan, *Chairman*
Ernest L. Ohle, *Secretary*
M. L. Holman

SOCIETY REPRESENTATIVES

1910

On John Fritz Medal

AMBROSE SWASEY (1)
CHAS. WALLACE HUNT (3)
F. R. HUTTON (2)
HENRY R. TOWNE (4)

On Board of Trustees United Engineering Societies Building

F. R. HUTTON (1)
FRED J. MILLER (2)
JESSE M. SMITH (3)

On Library Conference Committee

J. W. LIEB, JR., CHAIRMAN OF THE LIBRARY COMMITTEE, AM. SOC. M. E.

On National Fire Protection Association

JOHN R. FREEMAN
IRA H. WOOLSON

On Joint Committee on Engineering Education

ALEX. C. HUMPHREYS
F. W. TAYLOR

On Government Advisory Board on Fuels and Structural Materials

GEO. H. BARRUS
P. W. GATES
W. F. M. GOSS

On Advisory Board National Conservation Commission

GEO. F. SWAIN
JOHN R. FREEMAN
CHAS. T. MAIN

On Council of American Association for the Advancement of Science

ALEX. C. HUMPHREYS
FRED J. MILLER

NOTE—Numbers in parentheses indicate number of years the member is yet to serve.

OFFICERS OF THE GAS POWER SECTION

1909-1910

CHAIRMAN
J. R. Bibbins

SECRETARY
Geo. A. Orrok

GAS POWER EXECUTIVE COMMITTEE

F. H. Stillman (1), *Chairman*
G. I. Rockwood (2)
F. R. Hutton (3)
H. H. Suplee (4)
F. R. Low (5)

GAS POWER MEMBERSHIP COMMITTEE

H. R. Cobleigh, *Chairman*
H. V. O. Coes
A. E. Johnson
F. S. King
A. F. Stillman
G. M. S. Tait
George W. Whyte
S. S. Wyer

GAS POWER MEETINGS COMMITTEE

W. T. Magruder, *Chairman*
E. D. Dreyfus
C. W. Obert
W. H. Blauvelt
C. T. Wilkinson

GAS POWER LITERATURE COMMITTEE

C. H. Benjamin, *Chairman*
G. D. Conlee
R. S. de Mitkiewicz
L. V. Goebbels
L. N. Ludy
L. S. Marks
T. M. Phetteplace
G. J. Rathbun
R. B. Bloemeke
A. L. Rice
A. J. Wood

GAS POWER INSTALLATIONS COMMITTEE

L. B. Lent, *Chairman*
A. Bement
C. B. Rearick

GAS POWER PLANT OPERATIONS COMMITTEE

I. E. Moultrop, *Chairman*
J. D. Andrew
C. J. Davidson
C. N. Duffy
H. J. K. Freyn
W. S. Twining
C. W. Whiting

GAS POWER STANDARDIZATION COMMITTEE

C. E. Lucke, *Chairman*
Arthur West
J. R. Bibbins
E. T. Adams
James D. Andrew
H. F. Smith
Louis C. Doelling

Note—Numbers in parentheses indicate number of years the member is yet to serve.

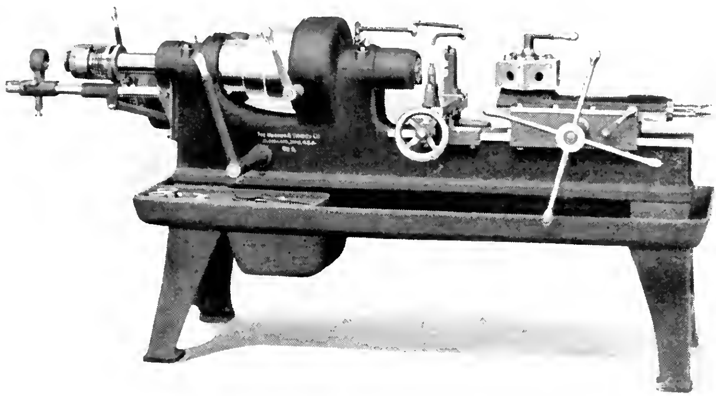
OFFICERS OF STUDENT BRANCHES

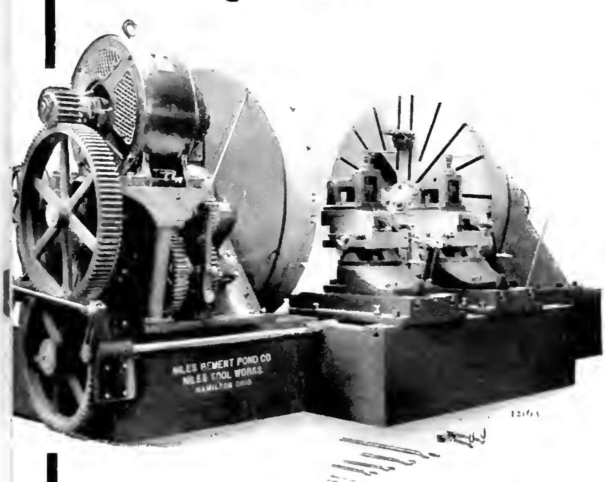
INSTITUTION	BRANCH AUTHORIZED BY COUNCIL	HONORARY CHAIRMAN	PRESIDENT	CORRESPONDING SECRETARY
	1908			
Stevens Inst. of Tech., Hoboken, N. J.	December 4	Alex. C. Humphreys	H. H. Haynes	R. H. Upson
Cornell University, Ithaca, N. Y.	December 4	R. C. Carpenter	....	F. E. Yoakum, Jr.
	1909			
Armour Inst. of Tech., Chicago, Ill.	March 9	G. F. Gebhardt	F. E. Wernick	W. E. Thomas
Leland Stanford, Jr. University, Palo Alto, Cal.	March 9	W. F. Durand	A. F. Meston	J. B. Bubb
Polytechnic Institute, Brooklyn, N. Y.	March 9	W. D. Ennis	J. S. Kerins	Percy Gianella
State Agri. College, Corvallis, Ore.	March 9	Thos. M. Gardner	C. L. Knopf	S. H. Graf
Purdue University, Lafayette, Ind.	March 9	L. V. Ludy	E. W. Templin	H. A. Houston
Univ. of Kansas, Lawrence, Kan.	March 9	P. F. Walker	C. E. Johnson	C. A. Swiggett
New York Univ., New York	November 9	C. E. Houghton	Harry Anderson	Andrew Hamilton
Univ. of Illinois, Urbana, Ill.	November 9	W. F. M. Goss	B. L. Keown	C. S. Huntington
Penna. State College, State College, Pa.	November 9	J. P. Jackson	G. B. Wharen	G. W. Jacobs
Columbia University, New York	November 9	Chas. E. Lucke	F. R. Davis	H. B. Jenkins
Mass. Inst. of Tech., Boston, Mass.	November 9	Gaetano Lanza	Morril Mackenzie	Foster Russell
Univ. of Cincinnati, Cincinnati, O.	November 9	J. T. Faig	W. H. Montgomery	P. G. Haines
Univ. of Wisconsin, Madison, Wis.	November 9	C. C. Thomas	John S. Langwill	Karl L. Kratz
Univ. of Missouri, Columbia, Mo.	December 7	H. Wade Hibbard	R. E. Dudley	F. T. Kennedy
Univ. of Nebraska, Lincoln, Neb.	December 7	C. R. Richards	M. E. Strieter	A. D. Stancliff
	1910			
Univ. of Maine, Orono, Me.	February 8	....	H. N. Danforth	A. H. Blaisdell
Univ. of Arkansas, Fayetteville, Ark.	April 12	....	....	....

ADVERTISING SUPPLEMENT

SECTION 1

Machine Shop Equipment



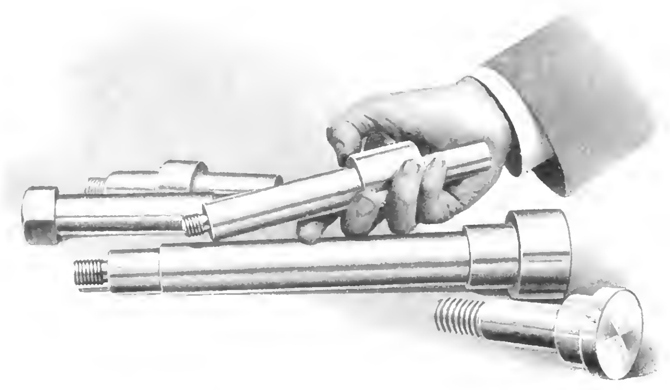

NILES BEMENT POND CO
NILES TOOL WORKS
HAMILTON OHIO

HARTNESS FLAT TURRET LATHE

Working Range for Bar Work

THE work shown on this page is the product of the 2 x 24-inch Flat Turret Lathe with the automatic die outfit (outfit D). This outfit gives the highest efficiency on such work. It turns all diameters up to $2\frac{1}{4}$ inches, and all lengths up to 24 inches, and cuts all U. S. standard screws from $\frac{3}{8}$ to $1\frac{1}{4}$ inches, inclusive, by sixteenths. (Whitworth, Metric or V standard furnished if desired.) Items of outfits on pages 86 and 87.

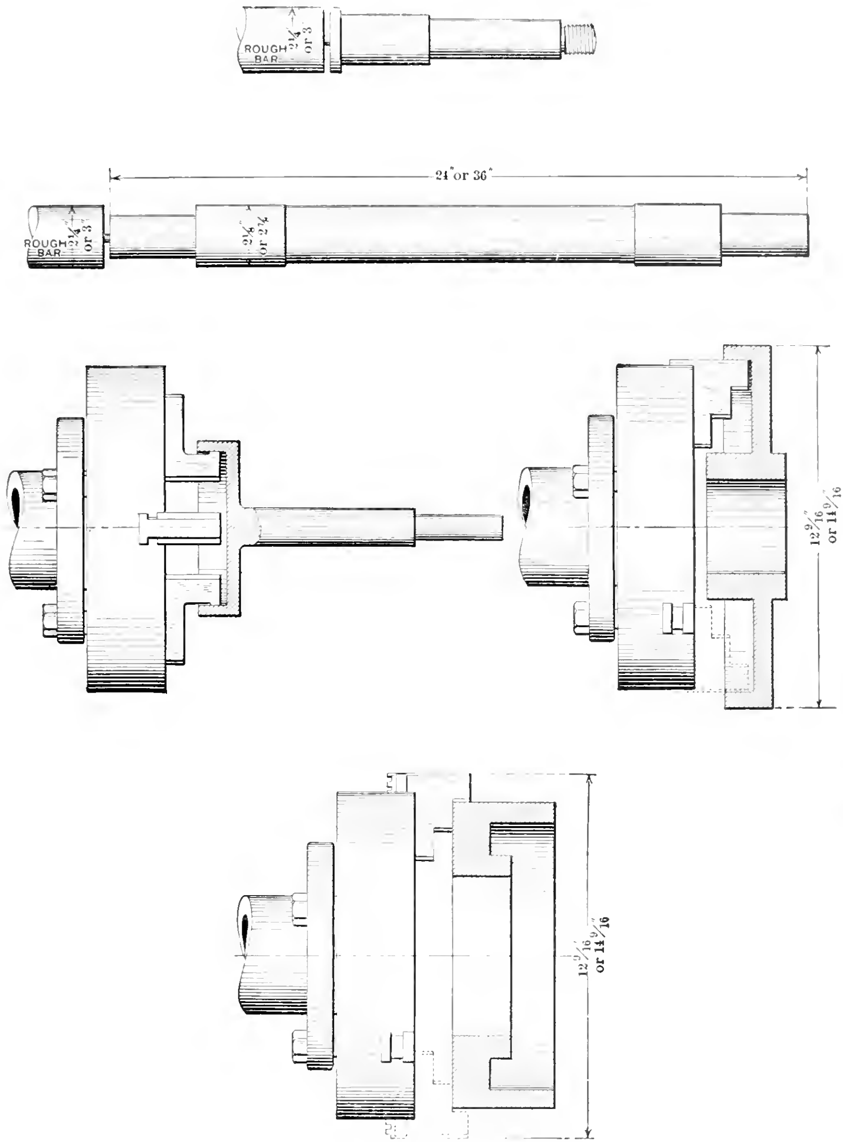
The same kind of work is turned out by the 3 x 36-inch with automatic die outfit; turning diameters from 3 inches down, and lengths up to 36 inches, and cutting screw threads from 1 to 2 inches, inclusive, U. S. standard. (Whitworth, Metric or V standard furnished if desired.)



Springfield, Vt.
U. S. A.

Jones & Lamson

Germany, Holland, Belgium, Switzerland, Austria-Hungary,
M. Koyemann, Charlottenstrasse 112 Dusseldorf, Germany.



Examples indicating working range and character of work covered by both machines

Machine Company

Queen Victoria St.
London, E. C.

France and Spain, Ph. Bonvillain and E. Ronceray, 9 and 11 Rue des Envierges, Paris. Italy, Adler & Eisenschitz, Milan

SECTION 2

Power Plant Equipment

BOOKS WANTED

The American Society of Mechanical Engineers desires to obtain, through donations, purchase or exchange, the following periodicals:

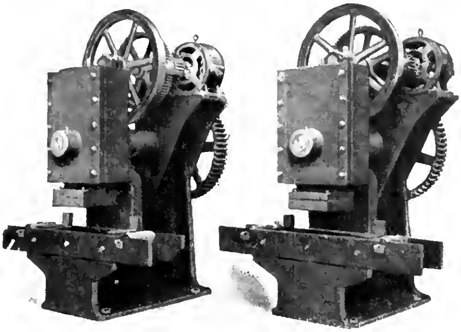
American Engineer, Chicago. Vol. 1. 1880.
American Gas Light Association. Vol. 1. Prior to 1875.
American Machinist. Vols. 1 and 2.
American Society of Naval Engineers. Vol. 1. 1889.
Mechanical Engineers, N. Y. Vols. 1-4. 1881-1882.
Scientific American. First Series. Vol. 1.
Die Gasmotorentechnick. Vols. 1-5, 6. Nos. 1-9.
Le Génie Civil. Vols. 1-23. 1880-1892
Glaser's Annalen für Gewerbe u. Bauwesen. Vols. 1-7 1865-1889.
Verein Deutscher Ingenieure. Vols. 1-7. 1857-63.
Der Schiffbau. Vols. 1-8.

The American Society of Mechanical Engineers

SECTION 3

Electrical Equipment

Westinghouse



A Westinghouse Motor for each Machine

means that each machine can be treated individually, and its producing capacity kept at a maximum, due to the ability of instantaneously adjusting the speed of the motor to every necessary variation in the producing speed of the machine. This is impossible with power derived through shafting, pulleys and belting.

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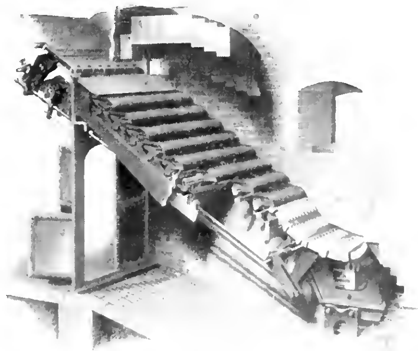
Sales offices in all large cities PITTSBURG, PA.

Member of American Association Electric Motor Manufacturers AAEMM

New Model Roney Stoker



Effects even combustion

Increases boiler capacity

Reduces maintenance cost

Easily applied to any boiler

For particulars, send for Roney Stoker Folder 4004

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Steam Turbines, Steam Engines, Gas Engines, Gas Producers, Condensers and Mechanical Stokers

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Boston, 131 State St.	Atlanta, Candler Bldg.	Philadelphia, North Amer. Bldg.
Denver, 512 McPhee Bldg.	St. Louis, Chemical Bldg.	San Francisco, Hunt, Mirk & Co.
Chicago, 171 La Salle St.	Pittsburg, Westinghouse Bldg.	Mex., G. & O. Braniff & Co., City of Mex.

ADVERTISING SUPPLEMENT

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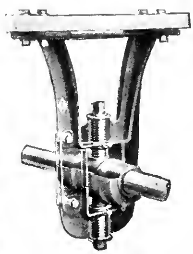

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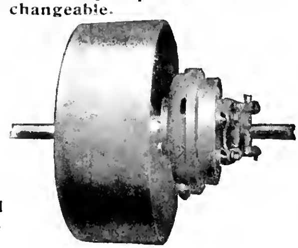

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Agencies in the Other Principal Cities of the Country

YEAR BOOKS

The Society wishes to have a file of year books or catalogues complete since its formation. Will members who have any of the following numbers either send them to the Society or correspond with the Secretary

No. 2, 1881	No. 6, 1885	No. 13, 1892, July
No. 3, 1882	No. 7, 1886	No. 14, 1893, January
No. 5, 1884	No. 12, 1891, July	No. 14, 1893, July

Also the 1903 edition of the Pocket List of Members

The American Society of Mechanical Engineers
29 West 39th Street, New York

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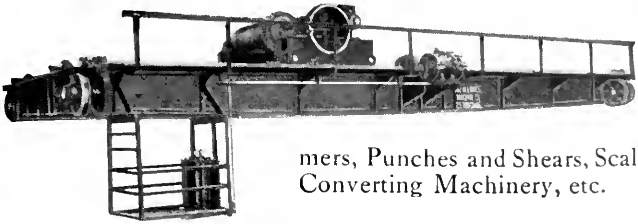

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THE ALLIANCE MACHINE CO. ALLIANCE, OHIO

Pittsburg Office, Frick Building. Birmingham Office, Woodward Building

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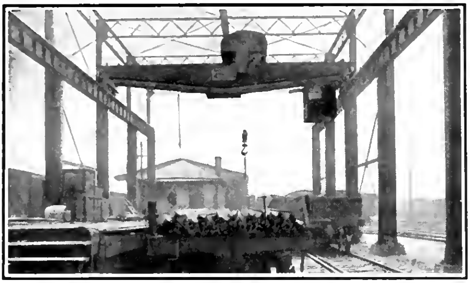
CRANES AND HOISTS

ELECTRIC AND HAND POWER
ALL TYPES AND CAPACITIES



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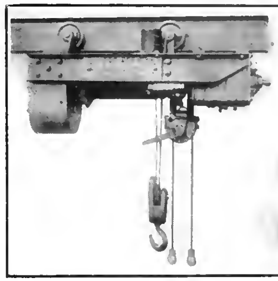

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Manufacturers, Engineers, Designers

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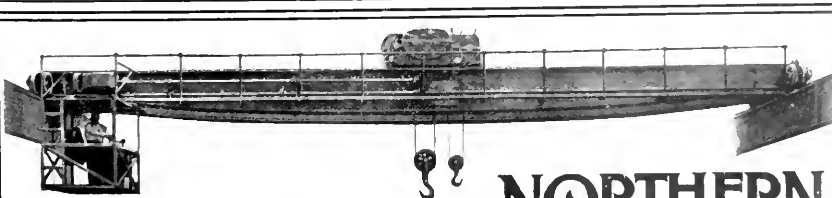

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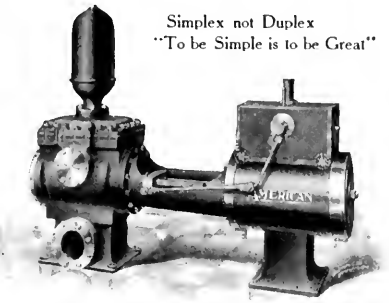
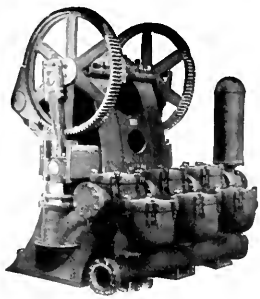
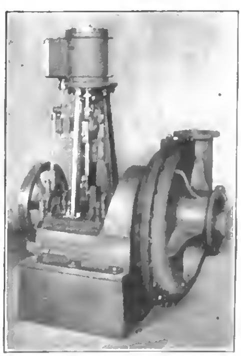
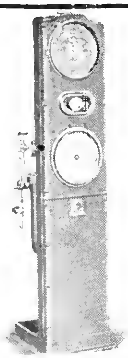
SECTION 5

Engineering Miscellany









SECTION 6

DIRECTORY
OF
MECHANICAL EQUIPMENT

A concise reference list of Machine Shop, Power Plant and Foundry Equipment; Pumping Machinery; Power Transmission Machinery; Electrical Apparatus; Hoisting and Conveying Machinery and allied lines.

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ALPHABETICAL LIST OF ADVERTISERS

THE

JOURNAL

THE AMERICAN SOCIETY
OF MECHANICAL ENGINEERS

CONTAINING
THE PROCEEDINGS

JUNE 1910

SPRING MEETING, ATLANTIC CITY, MAY 31 TO JUNE 3
MEETING IN ENGLAND, JULY 26 TO 29

JUNE 1910 VOL. 32 No. 6

THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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CONTENTS

THE JOURNAL is published by The American Society of Mechanical Engineers twelve times a year, monthly except in July and August, semi-monthly in October and November.

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THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 32 JUNE 1910 NUMBER 6

SPRING MEETING, ATLANTIC CITY, MAY 31-JUNE 3

PROGRAM

Tuesday afternoon and evening, May 31

Informal reunion of members in the parlors of the Marlborough-Blenheim.

Wednesday, June 1, 10 a.m.

PROFESSIONAL SESSION

Business meeting. Reports of Committees, Tellers of Election, New Business.

PAPERS ON MACHINE CONSTRUCTION AND OPERATION

A COMPARISON OF LATHE HEADSTOCK CHARACTERISTICS, Prof. Walter Rautenstrauch.

THE STRENGTH OF PUNCH AND RIVETER FRAMES MADE OF CAST IRON, Prof. A. L. Jenkins.

IMPROVED METHODS IN FINISHING STAYBOLTS AND STRAIGHT AND TAPER BOLTS AS USED IN LOCOMOTIVES, C. K. Lassiter.

THE SHOCKLESS JARRING MACHINE, Wilfred Lewis.

Wednesday afternoon and evening

The afternoon is left unassigned to give opportunity for sight-seeing. Roller chairs for the board walk will be available for the visiting members and guests through the courtesy of the Local Committee.

In the evening, entertainment on the Steel Pier has been provided by the committee.

Thursday, June 2, 10 a. m.

GAS POWER SECTION

BUSINESS MEETING AND REPORTS OF COMMITTEES.

PAPERS

A Regenerator Cycle for Gas Engines Using Sub-Adiabatic Expansion, Prof. A. J. Frith.

Gas Engines for Driving Alternating Current Generators, H. G. Reist.

Two Proposed Units of Power, Prof. Wm. T. Magruder.

Operating Experiences with a Blast Furnace Gas Power Plant, H. J. Freyn.

Thursday, 2 p. m.

PROFESSIONAL SESSION

MISCELLANEOUS PAPERS

The Mechanical Engineer and the Textile Industry, H. L. Gantt.

The Elastic Limit of Manganese and other Bronzes, J. A. Capp.

The Hydrostatic Chord, R. D. Johnson.

The Resistance of Freight Trains, Prof. Edw. C. Schmidt.

Thursday, 9 p. m.

Reception, followed by conferring of Honorary Membership on Rear-Admiral George W. Melville, U. S. N., Ret. A brief address will be made by Admiral Melville, and the evening will conclude with dancing and refreshments.

Friday, June 3, 10 a. m.

PROFESSIONAL SESSION

PAPERS ON POWER TRANSMISSION

Improvements in Lineshaft Hangers and Bearings, Henry Hess.

Experimental Analysis of a Friction Clutch-Coupling. Prof. Wm. T. Magruder.

An Improved Absorption Dynamometer, Prof. C. M. Garland.

Critical Speed Calculation, S. H. Weaver.

For several years the Spring Meeting of the Society has been held in cities where there has been an opportunity of visiting places of interest and inspecting engineering enterprises, and the time of the members has been very fully occupied in taking advantage of such excursions as the generosity and coöperation of the local members have made possible. While these meetings have all been thoroughly enjoyed, it was thought that it would be a welcome change to hold a meeting at a resort where those attending would have more time for renewal of acquaintance and for personal intercourse, instead of devoting so much attention to matters outside of the interests directly related to the Society and its membership. The last meeting of this sort was the Spring Meeting in 1903 held at Saratoga. The present meeting at Atlantic City should be an equally pleasant occasion, since there is no place in the country better adapted for holding a convention and the meeting is held at a time which is one of the most delightful in which to spend a few days on the New Jersey shore.

The headquarters of the meeting will be the Marlborough-Blenheim, situated at the central point of the board walk. The registration office will be located in the hotel, on the board walk floor, and the professional sessions will be held in the solarium on the office floor.

The Local Committee, chosen from the vicinity of Philadelphia, under the chairmanship of James M. Dodge, Past-President, Am.Soc. M.E., and with Arthur C. Jackson as secretary, is making provision for the entertainment. Through the courtesy of this committee, roller chairs on the boardwalk will be available and the use of the golf course at Pleasantville has been secured. Admission to the piers will also be arranged.

A Ladies' Committee has been formed with Mrs. Charles Day as chairman and will be in attendance at the headquarters to receive the visiting ladies and make their stay in Atlantic City most pleasant. A Bureau of Information will also be maintained.

LOCAL COMMITTEE

REPRESENTATIVES OF THE PROFESSION IN PENNSYLVANIA AND NEW JERSEY

JAMES M. DODGE, *Chairman* ARTHUR C. JACKSON, *Secretary.*

J. Sellers Bancroft
John Birkinbine
J. C. Brooks
Wm. C. Burnham
Harry W. Champion
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Geo. E. Titcomb
J. A. C. L. deTrempo
Wm. S. Twining
Harold Van Duzee
Mr. Van Gilder
S. M. Vauclain
William R. Webster
Tilden White
Walter Wood
J. E. Zimmerman

MEETING IN ENGLAND

A letter of detailed information covering all matters relating to the English meeting has been issued to all who have signified their intention of being in attendance there and particulars can be secured from the Secretary on request, by all who may be interested.

The party leaving New York on the official steamship Celtic, Saturday, July 16, at 2 p.m., will arrive in Liverpool Monday morning, July 25. Passengers will have a few hours for recreation on shore and will leave at noon by special train, for Birmingham, where they will be officially received by the Institution of Mechanical Engineers.

The Committee of the Society in charge of the arrangements is composed of Ambrose Swasey, *Chairman,* Charles Whiting Baker, *Vice-Chairman,* W. F. M. Goss, Geo. M. Brill, John R. Freeman, and George Westinghouse, Wm. H. Wiley, F. R. Hutton, Willis E. Hall, Calvin W. Rice, *ex-officio.*

PROVISIONAL OUTLINE OF MEETINGS

BIRMINGHAM PROGRAM

Monday, July 25

Afternoon.—Arrival in Birmingham.

Tuesday, July 26

Morning.—The Right Hon. the Lord Mayor of Birmingham and the Members of the Local Committee will receive and welcome the President, George Westinghouse, Esq., and the Officers and Members of the American Society of Mechanical Engineers, and the President, John A. F. Aspinwall, Esq., and the Council and Members of the Institution of Mechanical Engineers.

Reading and Discussion of Papers.

Luncheon in the Town Hall.

Afternoon.—Visits to Stratford-on-Avon, Worcester, Gloucester, or Bournville; and local Works.

Evening.—Garden Fête.

Wednesday, July 27

Morning.—READING AND DISCUSSION OF PAPERS.
LUNCHEON in the Town Hall.
Afternoon.—Visits to the University and local Works.
Evening.—RECEPTION in the Council House, by invitation of the Right Hon. the Lord Mayor of Birmingham.

Thursday, July 28

Visits to Works in Coventry and Rugby; also to Warwick, Leamington, Kenilworth, or Lichfield.

LONDON PROGRAM

Thursday, July 28

Afternoon.—Arrival in London.
Evening.—Conversazione at the Institution.

Friday, July 29

Morning.—PAPERS ON ELECTRIFICATION OF RAILWAYS.
Afternoon.—Garden Parties at private houses.
Evening.—INSTITUTION DINNER in the Connaught Rooms, Freemason's Hall, Great Queen Street, W. C. (Including Ladies.)

Saturday, July 30

Morning and Afternoon.—Excursion by rail and river to WINDSOR and HENLEY (by invitation).
Evening.—Reception at the Garden Club in the Japan-British Exhibition at the White City.

SOCIETY NOTES

MEETING IN ST. LOUIS, MAY 27

The monthly meeting of the Society in St. Louis, originally announced for May 14, is to be held on May 27 at the Engineers' Club of St. Louis. The paper by Prof. Edw. C. Schmidt on Freight Train Resistance, published in The Journal for May, will be presented.

BOSTON MEETING, APRIL 27

At the meeting of the Society in Boston, April 27, in which the Boston Section of the American Institute of Electrical Engineers and the Boston Society of Civil Engineers coöperated, the paper on The Testing of Water Wheels after Installation, by Prof. C. M. Allen, Mem.Am.Soc.M.E., was presented by the author. The paper was published in the April number of the Journal. The speaker was introduced by Prof. I. N. Hollis, Chairman of the Boston Committee. Slides were shown in connection with the paper, and there was discussion by R. A. Hale, of the Essex Water Power Company, John C. Parker, Mem.Am.Soc.M.E., Prof. Dwight Porter, Prof. George E. Russell, and Prof. H. K. Barrows, of the Massachusetts Institute of Technology, Henry D. Jackson of Boston, and Henry C. Daggett. Mem.Am.Soc.M.E.

ENGINEERS LICENSE COMMISSION

The introduction in the New York Assembly of a bill requiring certain classes of practising engineers to pass examinations and have licenses as a condition of practicing their profession, led the Council to appoint a special committee to investigate this matter and advise what action, if any, the Society should take. At a meeting of this committee on April 27, resolutions were adopted expressing the opinion that any legislation affecting the rights and status of engineers could be most wisely originated by conferences between legislators and representatives of the national engineering societies. It was also voted to request those having in charge this legislation, to postpone action until after the Spring Meeting of the Society at Atlantic City, and to have the subject brought up for

discussion there. The Council was also requested to appoint a committee of five to report upon any proposed legislation affecting the interests of members of the engineering profession.

PRESENTATION OF MEDAL TO DR. C. J. H. WOODBURY

The association medal of the National Association of Cotton Manufacturers was awarded to Dr. C. J H. Woodbury, Mem.Am.Soc.M.E., at the annual meeting of the association in Boston, April 27 and 28, 1910, in recognition of his work on the Bibliography of the Cotton Manufacture, and other services for the betterment of the industry. This medal, which was established in 1899, is awarded under very broad conditions that may include the author of any paper, a designer, either in mill construction or equipment, or of a process either of manufacturing or of finishing cotton goods. It has been given outside of the membership, although a member has generally been the recipient.

CORRECTION IN TRANSACTIONS, VOL. 26

The Forcing Capacity of Fire Tube Boilers by F. W. Dean, Transactions, Vol. 26, p. 93, in table, Par. 6, the last six items refer to fire-tube boilers instead of water-tube boilers.

CORRECTION IN TRANSACTIONS, VOL. 29

Ball Bearings, by Henry Hess, Transactions, Vol. 29, p. 447, caption of Fig. 14, Relation of Compression and Load for the Three Tests, Item 2 should read:

"2 balls $\frac{5}{8}$-in. diameter and flat disc. Compression according to Hertz $\frac{\delta}{2} = 0.0000805 \sqrt[3]{P^2}$"

STUDENT BRANCHES OF THE SOCIETY

STANFORD UNIVERSITY

The Stanford Mechanical Engineering Society, affiliated with The American Society of Mechanical Engineers, held its regular meeting on April 6, when Prof. Harris J. Ryan, Mem.Am.Soc.M.E., gave an interesting talk on the Los Angeles aqueduct, outlining its course of construction and showing the possible utilization of available power sites. A business meeting was held on April 20.

UNIVERSITY OF MAINE

Two papers were presented at the meeting of the student branch of the University of Maine on April 27: The Electric Car Control, by G. B. Chapman, being in the main a description of the hand and air-brake systems as used on electric cars, and The Modern Locomotive, by C. G. Cummings (1910), briefly describing the historical development, and discussing the different types of modern locomotives in use at present.

PENNSYLVANIA STATE COLLEGE

A meeting of the Pennsylvania State College student branch was held on April 28 and three papers were presented, on Applications of Refrigeration and the Manufacture of Artificial Ice, by Guy W. Jacobs (1910). The Different Processes of Mechanical Refrigeration, by George O. Weddell (1910), and The Design of a Cold Storage Plant, by Wm. R. Mollison (1910).

DEATH OF WALTER CRAIG KERR

Announcement is made of the death of Walter Craig Kerr, May 8, 1910, at Rochester, Minn. An account of his life will appear in an early number of The Journal.

OPERATING EXPERIENCES WITH A BLAST FURNACE GAS POWER PLANT

By Heinrich J. Freyn

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OPERATING EXPERIENCES WITH A BLAST FURNACE GAS POWER PLANT

By Heinrich J. Freyn

Member of the Society

The use of blast furnace gas engines in this country was first undertaken in 1902 by the Lackawanna Steel Company at Buffalo, followed four years later by the United States Steel Corporation in several of its plants. The import of the problem of utilizing the surplus gas may be realized by considering that eleven million tons of pig iron were produced in 1909 by the United States Steel Corporation, and that for each ton of iron made per day, 25 b.h.p. is available for purposes outside of the power requirements of the blast furnaces, provided this power is itself produced in gas engines. If, therefore, all the blast furnaces of the corporation were blown by gas blowing-engines and all other furnace requirements furnished by gas-electric engines, 750,000 b.h.p. would be available for other purposes.

2 In 1907 there were installed at one of the largest steel plants in this country, four Allis-Chalmers double-acting, four-cycle, twin tandem gas engines, gas cylinders, 42-in. diameter, 54-in. stroke, operating 2000-kw., 25 cycle, 3-phase, 2200-volt, alternating-current generators at 83.3 r.p.m. This addition to the existing steam-electric equipment was completed in 1908 and the electric power produced by these gas engines is used for electric-driven rolling mills and general light and power purposes. The gas-driven generators operate parallel with the adjacent steam units and with other gas-driven generators located 20 miles away.

3 The gas engine plant under discussion has been in regular service for one and one-half years, during which period the experiences and results described in the following pages were obtained.[1] These

[1]These experiences and records were compiled with the able assistance of Mr. Chas. C. Sampson, Mem.Am.Soc.M.E.

The American Society of Mechanical Engineers, 29 West 39th Street, New York, June 1910. All papers are subject to revision.

were not gathered from the indications of one single experiment, or of a series of carefully prepared and conducted tests, but represent the average results of daily observations extending over one year's time. Since the degree of correctness depends on the accuracy of observation and care in recording the results of persons having various degrees of practical and technical training, inaccuracies entailing puzzling inconsistencies may have crept in and the data presented may not in every instance withstand the test of searching criticism; nevertheless it is believed that such information, derived from actual operation, will prove of more interest to the engineering profession than unassailable data obtained under test conditions.

4 The gas supply for the operation of all the gas engines of the plant is taken from six blast furnaces, all of which in 1909 were blown by steam blowing-engines, while the electric power for the plant was derived from both steam and gas-driven generators. This plant is therefore a so-called "mixed" plant, so far as the generation of power is concerned.

5 The quantity of blast furnace gas available for the operation of gas engines was therefore considerably less than it will be when four of these furnaces are blown by gas blowing-engines. Because of the general business depression at the beginning of 1909, only three, and in the months of March and April only two, furnaces were in blast. Normal conditions were resumed about May or June, while all six furnaces were in blast during the months of September and October only.

CONDITIONS OF INSTALLATION

6 The gas power station in question was conceived in 1905, and all preliminary calculations relative to the amount of gas available for operating gas engines were naturally based on the conditions existing at that time, making the proper deductions for reduced gas production due to the furnaces being out of blast for relining. Careful investigations showed that in 1906, 10 per cent of the total gas produced by six blast furnaces, equivalent to 10,200 kw., was available for use in gas-electric engines. The installation of 8000 kw. in gas engines seemed therefore fully warranted, particularly as it was expected that two gas blowing-engines simultaneously ordered would be in operation after November 1907, in which case the gas surplus, even with only five furnaces in blast (one furnace down for relining) would have been more than ample to operate four 2000 kw. of gas-electric units. It could not be foreseen that business conditions would

change so radically in 1908, nor that the two gas blowing-engines would be so delayed, that for three years the saving of gas, which would have materially improved conditions for the electric units, could not be realized.

7 While the logical way to begin would have been with the installation of a number of gas blowing-engines, instead of first taking gas-electric engines in operation, increasing instead of reducing the available quantity of blast-furnace gas, such a procedure was impossible because of the immediate demand for increased electric power created by the installation of new electrically operated mills, as well as on account of local conditions of steam supply for the furnaces, which at that time prohibited the removal of a large boiler house, now occupied by the new gas blowing-engines. From the circumstances, however, that gas-electric engines were installed before any gas blowing-engine equipment existed, and that this power plant, as it so happened, had to be operated for almost two years under the most unfavorable and exacting conditions, a great deal of most valuable experience was gained, in that it was found that such a power plant could be maintained in operation—although with interruptions—with only two furnaces, and for a short period even with only one furnace in blast.

OUTPUT OF POWER PLANT

8 In Appendix No. 1, Table 1 shows the average kilowatt-hour produced by the gas power plant for each month of 1909, from which it appears that the average for the year was 5760 kw-hr., or 72 per cent of the total capacity of the plant, and this average for various months varied from 66.5% to 74% with two furnaces, 61.5% to 80.5% with three, 69% for four, 64% to 82.5% with five, 68.5% to 78% with six furnaces in blast. While during the first few months the number of furnaces in blast was very limited, the total output of the station was nevertheless not affected very materially. In fact, in the month of March, when only furnaces No. 1 and No. 2 were in blast, 74% of the total capacity of the plant was produced, a higher figure than the average output of the plant for the whole year.

SHUTDOWNS AND TIME LOST IN OPERATION

9 A record is being kept as correctly as practicable of all shutdowns and their causes. Table 2, in Appendix No. 1, gives the monthly averages, as well as the percentages of operating time and of time lost chargeable to the engines, and due to outside causes. The

power station is considered in this table as one unit, and the figures are averages applying to the four engines.

10 In Appendix No. 1, Table 2, is given the average monthly operating time of the station for the whole year, from which it appears that the average for the year was 77% of the total possible time, 14.2 % and 8.8% being the percentages of the time lost due to engine repairs and to outside causes beyond control. The respective figures for the first four months of the year show that the operating time from January to April was much lower than during the rest of the year, the lowest figure being 57% in January. However, the month of March with 71% shows again the noteworthy fact that with only two furnaces in blast the operating time was higher than the average for the first half of the year. This was made possible only by shutting off the boiler houses almost entirely. With the boiler houses off, blast furnace No. 1 made more gas than the gas engines, the stoves and one small boiler house could use, so that one bleeder at the furnace had to be kept open. During casting periods the engines were operated on the gas tank. In this manner operation was kept up for one whole week. The time lost chargeable to the engines is considerable for the first four months, due to the fact that owing to the uncertainty of sufficient gas supply under the existing conditions of furnace operation certain repairs and alterations were made on the engines, which otherwise would have been distributed over a longer period of time. It is to be noted that any time lost is rigorously charged against the engines if the latter for any reason are not ready to resume operation at any moment.

11 The time lost due to outside causes was particularly heavy in the first four months of the year, varying from 11½% in April to 19½% in February. In the records the lost time chargeable to outside causes is subdivided into losses due to operation of the plant, such as line troubles, or output not required, etc.; and losses due to lack of gas. This particular information is given in Table 3 of Appendix 1, wherein the plant is again considered as one unit. Shortage of gas was responsible to the greatest extent for lost time from outside causes in the first four months of the year. In January this figure was as high as 94.5 %, and while the average for the first half of 1909 exceeds 60%, the corresponding figure for the second half of 1909 is only 3%.

CONSIDERATIONS OF SAFETY WHEN THERE IS SHORTAGE OF GAS

12 Although the difficulties which were experienced in this period by the frequent inability of the blast furnaces to supply sufficient gas

to maintain operation of the whole plant, without heavily firing coal under the boilers, had no serious effect on the gas power plant, one important question was in the minds of all during this period, namely the safety of the installation. Antedating only a few months this period of gas shortage, a serious accident had happened at another plant where through lack of gas while only one furnace was in blast, the preliminary cleaning plant, the gas holder and parts of the pipe line conveying gas to the engines, exploded with disastrous effect. This accident caused a great deal of uneasiness and alarm in other gas engine plants where several furnaces were out of blast.

13 A gas power plant is endangered in two ways by lack of gas, either from collapsing of the gas holder bell or from explosion. In modern gas-cleaning installations, the so-called secondary washing plant, which refines the gas for use in engines, is usually equipped with some kind of rotary washers. Certain washers of this type, such as the Theisen, can give a vacuum of 3 in. of water, and a discharge pressure from 8 in. to 10 in. higher than the positive or negative pressure on the suction side. The washers deliver the gas to a gas holder under variable pressure dependent upon the raw gas pressure, while it is the principal object of the gas holder to maintain a constant gas pressure at the gas engines, irrespective of what the pressure at the blast furnaces or in the gas-cleaning plant happens to be. As long as the pressure of the gas, and therefore its quantity, is sufficient to allow the rotary washers to keep the gas-holder bell floating; in other words as long as balance exists between the demand for gas on the part of the engines and the supply from the furnaces, there is no danger to the installation.

14 If the gas supply falls below the demand, the volume of gas in the holder will cover the shortage within the limit of its capacity and until the bell, descending completely, rests on its landing beams. The rotary gas washers will then continue to operate, creating a depression in the gas conduits by which they are connected to the gas main at the furnaces. The latter is virtually a large gas receiver into which all blast furnaces discharge their gas, and which in turn supplies the hot-blast stoves, the boilers, and the gas-cleaning plant. The vacuum created by the rotary washers will naturally be communicated to this main gas flue, but cannot be maintained as the overhead flue is connected with the atmosphere through hot-blast stoves and boiler stacks. Air will therefore rush into this flue and into the gas-cleaning plant and be drawn into the rotary washers together with whatever gas is supplied, and discharged into the gas holder.

As long as these conditions exist, the gas-holder bell is not in danger from collapsing, but there is imminent danger from explosion to the whole plant. Rotary gas washers do not discriminate between gas and air, and continue to operate, filling all gas flues, gas holder and engine connections with a mixture of gas and air which under certain conditions is highly explosive. Should backfiring occur in the gas engines when receiving a mixture of gas and air instead of pure gas; that is, should the fresh incoming charge accidentally be ignited, consequences would be as prompt as disastrous —the air and gas mixture in the pipe system would explode, possibly wrecking the whole installation by a series of explosions.

15 This is precisely what did happen in the accident mentioned, and profiting by this experience steps were taken to prevent the occurrence of such an accident at the plant under discussion. Power house, gas washing plant and blast furnace office were connected by two independent telephone lines, and recording instruments, in addition to ordinary U-tubes, were installed in the washer building and at the blast furnace office, so that not only may the gas pressure be observed at any time, but it is automatically recorded for each period of 24 hours. Moreover an automatic alarm was installed at the blast furnace office, which rings a bell as soon as the gas pressure in the raw gas descends below a certain danger point, and whistle signals operated by solenoids from the blast furnace office were provided in the boiler house to inform the head fireman of the number of boilers to be "taken off" or put on gas. In addition an automatic bell was placed in this boiler house, calling the operators' attention to any drop below normal in the gas pressure.

16 Independently of the blast furnace department, the gas-cleaning plant operators were also carefully watching the gas pressure. The position of the gas-holder bell was made visible at any time by a system of incandescent lamps in the washerhouse, and strict orders regarding the use of the gas were issued by the blast furnace superintendent, instructing the men to favor the gas engines under any circumstances, as it was fully recognized that having taken care of the requirements of the hot-blast stoves, the remaining gas could not possibly be more efficiently utilized than in the gas engines. The practice was to shut off the gas immediately at a certain number of gas-fired boilers, as soon as the pressure in the overhead gas flue dropped below a predetermined point. Additional boilers were taken off if the gas pressure did not recover, so that sometimes as many as 24 boilers were being fired by coal exclusively. If this did not have

the desired result, stoves were taken off for short periods to increase the gas pressure above the danger point. At last, if all these steps did not improve the situation, one or more gas engines were shut down.

17 Fortunately in the majority of cases the blast furnace operators know in advance if the gas supply is likely to fail, and communication could easily be established to warn the departments concerned of the impending gas shortage. The diagram, Fig. 1, plotted from a

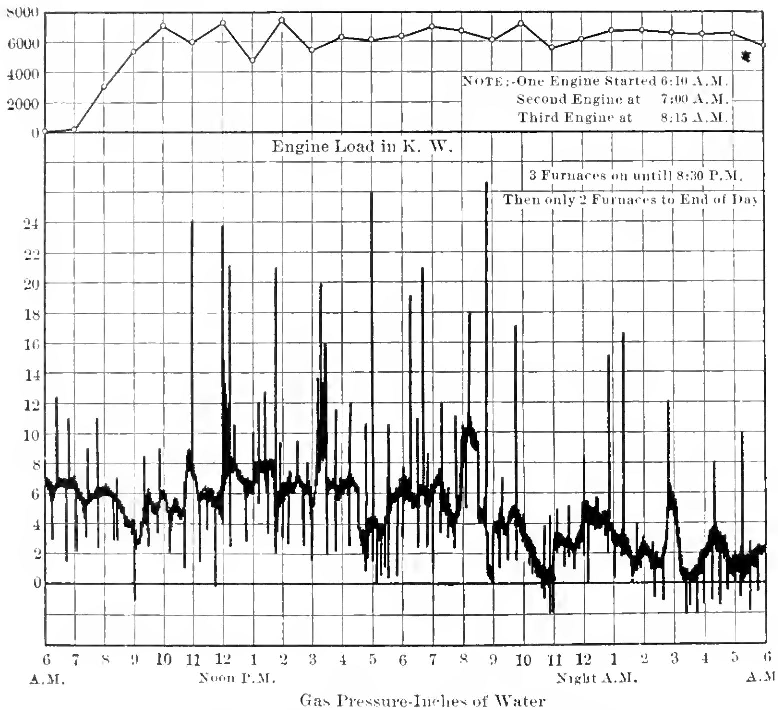


FIG. 1 DIAGRAM PLOTTED FROM BRISTOL CHART SHOWING GAS PRESSURE WHERE THE GAS ENTERS THE GAS-CLEANING PLANT

Bristol chart representing a 24-hour record of the gas pressure at the point where the gas enters the gas-cleaning plant, is a good illustration of the conditions existing on many occasions.

18 The system of close observation and of coöperation among the departments concerned worked to perfection, but nevertheless conditions existed at times which with all due optimism had to be called dangerous. It was frequently necessary to keep several gas engines running, with the gas pressure dropping below the danger point

momentarily or even for periods of a few minutes. This was unavoidable if the operation of certain departments dependent upon a supply of electric power was to be maintained with any regularity. If the gas engines had been shut down every time a momentary drop in pressure occurred, it would often have meant an endless amount of shutting down and starting of engines, altogether too frequent for satisfactory operation of the mills, and physically impossible for the gas engine operators.

19 The question whether an automatic safety device should be installed at the power plant under discussion was thoroughly considered and such devices were investigated; but it was decided that the installation of costly safety appliances, which were certain to become inoperative with the normal number of furnaces in blast, was not warranted, as the conditions of gas shortage were exceptional and of temporary nature only. Besides, automatic safety devices, no matter how ingeniously designed, are never "foolproof," and have the reputation of operating without cause and of failing to act when needed. A further drawback is the tendency to over-confidence in the infallibility of a safety device. In this respect gas-cleaning plants should be classed with boiler plants, where the "human element" cannot be eliminated, and safety depends ultimately upon the rigid enforcement of certain established regulations. Responsible operators can use good judgment which automatic safety devices do not possess to decide whether shutdowns are necessary when low gas pressure occurs, possibly for a moment only. This was proved time and time again at the plant under discussion.

20 If such safety devices are considered necessary, however, the arrangement of automatic circuit breakers to shut off the power at the rotary washers, and simultaneously interrupt the ignition circuit of the gas engines, is decidedly better for safeguarding the plant than the installation of butterfly or check valves between rotary washers and gas holder, which shut off delivery under the control of the gas pressure. While in both cases the aspiration of air by the rotary washers is effectively prevented, the former device protects not only the gas cleaning plant but also the gas holder, while the latter may cause collapsing of the holder bell by isolating it from the gas supply.

QUANTITY AND QUALITY OF GAS SUPPLIED TO ENGINES

21 The amount of gas produced by each blast furnace is calculated and distributed in proper proportion among the different places of its consumption. Monthly gas-distribution sheets give a record of

the average daily tonnage of each furnace, the kind of blast, whether natural or dry, the kind of coke used and the coke consumption per ton of iron; further, the average gas analysis for each furnace based on daily determinations of continuous 24-hour samples, the heat value per cubic foot at 62 deg. fahr. and including the sensible heat of the gas at 500 deg. fahr., the temperature of the air at the blowing engines, the number of cubic feet of air blown per minute, and the average blast pressure. From these data the quantity of gas produced by each furnace per minute is calculated according to methods given in Appendix No. 2. The distribution of the gas from one blast furnace based on such calculations is given in the accompanying table (Table 1 herewith), reproduced from data given in Appendix No. 2.

TABLE 1 DISTRIBUTION OF GAS FROM BLAST FURNACE NO. 6

August, 1909

	Million B.t.u.	Per Cent
Total Gas Generated	324.1	100
Stoves and leakage	130.0	40.
Blowing engines	92.1	28.4
Used at furnace	9.0	2.8
Auxiliaries	4.6	1.4
Total used for blast furnace operation	235.7	72.6
B.t.u. surplus for furnace	88.4	27.4
B.h.p. equivalent of surplus	1470	

22 An excellent practical indicator of the gas quantity available for engine operation is the gas pressure at the cleaning plant. With more than three furnaces in blast the pressure is always sufficiently high to make operation of the gas power station perfectly safe. Fig. 2 shows the average monthly gas pressure at the main water seal

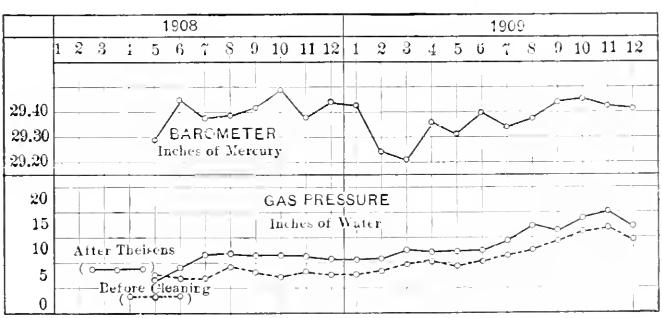


Fig. 2 Gas Pressure Curves—Barometric Pressure (Monthly Averages)

where the gas enters the cleaning plant and in the fine gas main after the secondary washers.

23 While the quantity of blast furnace gas was subjected to considerable variation due to the generally unfavorable conditions which existed in the early part of 1909, the quality of the gas was also found to vary materially, so far as its chemical composition and heat value were concerned. These were influenced not only by changes in the furnace burden and by the kind of product, whether basic iron, Bessemer iron, spiegeleisen or ferrosilicon, but by other causes to which variations frequently recorded from hour to hour, to a large extent could be traced. The blast furnaces discharge their gas into one common overhead gas main supplying stoves, boiler houses and gas engines. The intake for the gas-cleaning plant is located between furnaces No. 2 and No. 3, dividing the total length of the overhead flue in the proportion of one to two, approximately. In view of this central location of the intake nozzle it was expected that by mixing the gas from these furnaces a fairly uniform quality, representing the average of all six furnaces, would be obtained for engine operation. Due to the location of the boiler houses, however, this uniformity of mixture could not be realized.

24 Fig. 3 shows the existing conditions previous to May 1909, and before the boiler plant for four blast furnaces was abandoned in order to make room for the new gas blowing-engine house. The tall boiler stacks caused a flow of gas from furnaces No. 1 and No. 2 to the boiler house situated at the west end of the flue, while the gas from furnaces Nos. 4, 5 and 6 went to two large boiler houses located at the opposite extremity. The gas-cleaning plant received, therefore, almost exclusively gas from furnaces No. 2 and No. 3 or from No. 3 alone, while No. 2 was out of blast. This was proved beyond any doubt by frequently comparing the chemical analysis of the gas delivered at the power station with the analyses of the gas of the individual furnaces.

25 Thus for the month of June 1908 the average composition of the gas from blast furnaces Nos. 1, 3 and 4, which are in close proximity to the gas-cleaning plant intake, was as follows (blast furnace No. 2 being out of blast and blast furnace No. 4 on spiegel):

Blast furnace No.	CO_2	CO	H	$\frac{CO}{CO_2}$	B.t.u.
1	13.5	25.0	3.4	1.85	93.3
3	12.4	26.7	3.2	2.15	98.1
4	5.1	32.1	3.3	6.30	115.2

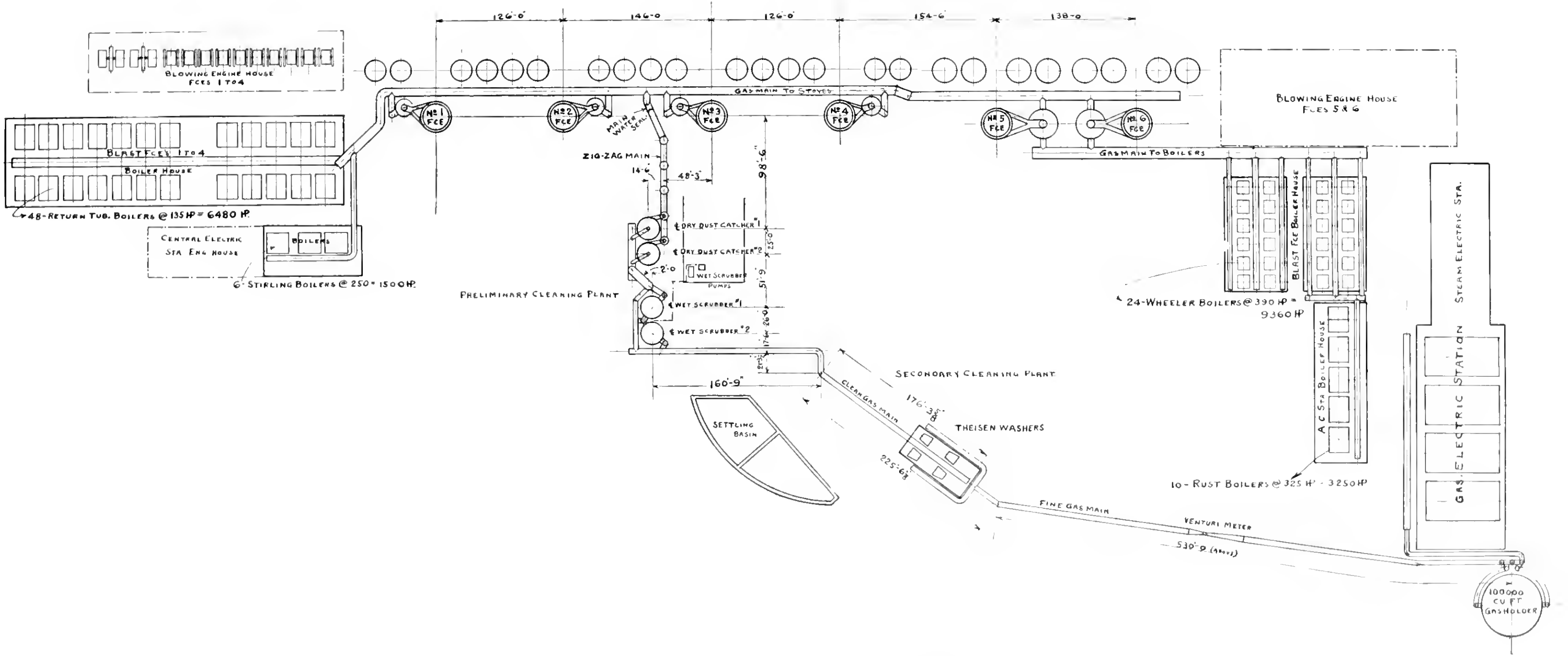


Fig. 3 Arrangement of Gas Power Plant 1908

The average composition of the gas at the power station for the same period was:

CO_2	CO	H	$\frac{CO}{CO_2}$	B.t.u.
12.6	26.64	3.2	2.33	96.73

The analyses of the gas of blast furnace No. 3 and the gas at the power house, coincide very closely, establishing proof that during this time this one furnace was furnishing the gas for the engines almost exclusively.

26 Since abandoning the boiler house for blast furnaces Nos. 1 to 4, which now receive steam through a 14-in. steam line from the boiler house at the east end, all gas from furnaces Nos. 1, 2 and 3 is being delivered to the gas-cleaning plant, with the exception of a small portion which goes to a small boiler house at the west end, while the gas of the remainder of the furnaces flows in the same direction to the boiler houses of furnaces Nos. 5 and 6 and the electric station. To illustrate the present condition of gas distribution, comparative data were compiled, given in Tables 3 and 4 in Appendix 2, which give the averages of gas analysis and heat values of the individual six furnaces, all of which were in blast in September 1909 and the average composition of mixtures of the gas from various furnaces calculated from the former. For the same month when these averages were taken the average composition and heat value of the gas delivered at the power house were:

CO_2	CO	H	CO_2	B.t.u.
10.03	29.80	3.77	2.98	108.70

Comparing this analysis with the mixture characteristics, given in Table 4, Appendix 2, the gas appears to be most nearly equivalent to the mixture from furnaces Nos. 1, 2 and 3 together.

27 Conditions were decidedly better in the second half of 1909, so far as uniformity of the gas supplied to the engines is concerned, but it is easily seen that changes in furnace operation must even under present conditions affect the quality of the engine gas. Whenever the gas supply from the furnaces on which the gas-cleaning plant is directly drawing happens to cease, in other words during checks or repairs, or if one or several of these furnaces are in trouble, disturbances are created in the regular flow and therefore in the quality of the gas, so that momentarily, or for longer periods, richer or leaner gas from other furnaces near the gas-cleaning plant intake is delivered to the gas engines. That such disturbances exist was very strikingly

proved in many instances. The gas engines, which had been operating smoothly, apparently receiving very uniform gas, would suddenly begin to backfire, or to have premature explosions and become very unsteady. These abnormal occurrences would be repeated at short intervals, although possibly lasting only a few minutes. The operating engineers soon discovered the cause of their troubles, and reported in their language that "a bad batch of gas" had caused the backfiring or the premature explosions and the "swinging" on the line. Such pronounced "waves" in the quality of the gas will often affect first the engine nearest to the gas holder, the trouble gradually extending to the engines down the line, and will stop first at the engine where the trouble started, gradually lessening on the rest of the engines, or else all engines will be affected simultaneously.

28 These interesting phenomena, and their bad effect on the parallel operation of the gas engines, prompted investigations which almost invariably located the causes for the sudden increase in hydrogen and methane. It was found that slipping of the furnaces was very frequently followed by backfires and premature explosions; and whether or not part of the raw wet stock in the furnaces reaches the incandescent zone, due to the upheaval of the material inside the furnace during slipping, thereby causing the formation of excessive amounts of hydrogen, remains an open question. Violent premature explosions and backfiring could in very many cases also be traced back to leaking tuyeres or hot blast valves, and these were so pronounced at times that the gas engines often fairly served as an indicator of such leaks.

29 The following gas analyses made on February 10, 1909, at the power house, give a good illustration of the suddenness of these changes:

GAS ANALYSES AT POWER STATION LABORATORY

ENGINE GAS

Time	CO_2	CO	H	CH_4	B.t.u. by analysis
11.00 a.m.	14.9	24.5	3.5	0.2	90.9
12.30 p.m.	13.8	24.7	4.3	0.3	94.6
3 30 p.m.	14.5	25.0	6.5	0.1	99.9
4.10 p.m.	14.2	24.8	4.5	0.2	94.7

The increase in hydrogen of almost 100 per cent between the first and third analyses is noteworthy. The effect on the engines was the occurrence of violent premature explosions around 3 o'clock of that

day. Backfiring happened simultaneously on three engines in operation on August 17, 1908, and was caused by fluctuations in the composition of gas. The daily chemical report for 24 hourse nding 6.00 a.m., August 18, contains the following record:

CHEMICAL ANALYSIS, AUGUST 18

Time	CO_2	CO	H	CH_4	B.t.u. by analysis
9.30 a.m.	10.9	27.6	3.6	0.2	101.2
1.30 p.m.	6.4	33.2	4.4	0.2	121.6
2 00 p.m.	8.4	30.2	4.4	0.2	111.9
4.00 p.m.	8.0	30.2	3.5	0.2	109.4

30 The simultaneous calorimeter determinations gave the following heat values:

CHANGE IN HEAT VALUE BY CALORIMETER

Time	B.t.u.	Time	B.t.u.
9.00 a.m.	101.3	1.00 p.m.	115.2
9.30 a.m.	102.7	1.30 p.m.	118.3
10.00 a.m.	103.9	2.00 p.m.	110.7
10 30 a.m.	105.0	2.30 p.m.	110 3
11.00 a.m	105.9	3.00 p.m.	112 0
11.30 a.m.	106.4	3.30 p.m.	108.5
12.00 m.	108 6	4 00 p.m.	109 3
12 30 p.m.	109.5	4.30 p.m.	110 4

The heat value of the gas increased almost 20 B.t.u., or about 20 per cent in less than three hours, due to heavy coke blanks charged at blast furnace No. 1 which was in trouble. In this particular instance it was the sudden increase in carbon monoxid which caused the backfiring. It was not always possible, however, to prove by analysis or by calorimeter test that a sudden change in the heat value of the gas or a momentary increase in hydrogen had taken place when premature firing occurred; nevertheless, following the example of the Lackawanna Steel Company, the pressure of the cooling water for tuyeres and hot blast valves was reduced to a little below the normal blast pressure on all furnaces. Thus water-leaks into the furnaces were very effectively stopped and one principal cause for premature explosions at the engines was removed.

31 The kind of iron produced by the different furnaces at different times had a considerable effect upon the quality of the gas. Thus in September 1909 the average heat value of the gas at the power station was 108.7 B.t.u. per cu. ft., because during this month blast furnace

No. 1 was making ferrosilicon with a coke consumption of over 4600 lb. per ton of product. The average analysis of the gas of this furnace is given in Table 3, Appendix 2, and the composition of the engine gas for September is given in Par. 26 of the paper. The richest gas which the engines ever received occurred September 17, 1909, the average of the analyses for the day being as follows:

CO_2	CO	H	CH_4	$\frac{CO}{CO_2}$	B.t.u. by analysis
4.7	34.9	3.2	0.16	7.92	123.3

The average corresponding B.t.u. values determined by calorimeter were 122.5 per cu. ft. The influence of this rich gas on the operation of the engines is shown in the daily record of engine operations for the same day. Three engines were running and were backfiring and hav-

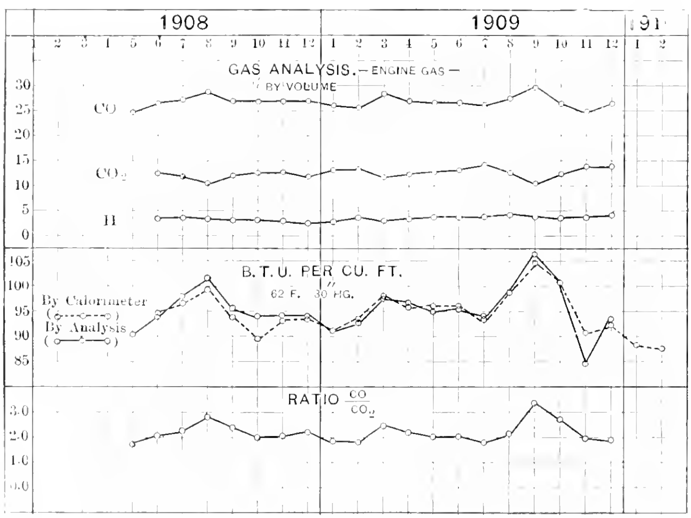


FIG. 4 GAS ANALYSIS AND HEAT VALUE OF BLAST FURNACE GAS (MONTHLY AVERAGES)

ing premature explosions all day long. On the following day the operating engineer reported that the gas made a quick change about 1.00 a.m. to very poor quality, causing all engines to misfire and to drop about one-half of their load, and the richness of mixture had to be changed on all engines to obtain proper ignition. About 2.00 a.m. the gas became suddenly very rich and the engines again backfired heavily, necessitating additional changes in the mixture. The leanest gas

on which these engines were operated during the year 1909 occurred in November, the average composition for the month being as follows:

CO_2	CO	H	CH_4	$\frac{CO}{CO_2}$	B.t.u.
13.8	24.7	3.59	0.19	1.79	86.7

The lowest daily average heat value occurred on November 16, with gas of the following analysis:

CO	CO_2	H	CH_4	$\frac{CO}{CO_2}$	B.t.u. by analysis
15.8	22.1	3.3	0.3	1.39	83.1

The gas was so poor that day that it was impossible to keep it burning in the calorimeter. The lowest heat value ever recorded is 79.5 B.t.u. per cu. ft. on November 17, the gas analysis at 12.00 o'clock noon giving the following results:

CO_2	CO	H	CH_4	$\frac{CO}{CO_2}$	B.t.u. by analysis
17.1	21.6	3.1	0.1	1.26	79.5

The effect of such very poor gas on the engines is quite noticeable; the full output of the generators could not be maintained, although the proportion of air and gas was changed to meet the new conditions.

32 In Appendix 2, Table 5, is given the average composition of the blast furnace gas for each month, averages for the first and second halves, and the average for the whole year of 1909; further, the heat value of the gas determined by calorimeter. In Fig. 4 herewith these values are plotted for each month since June 1908 when the systematic records were begun. The discrepancies in the heat values as computed, and as determined by Junkers calorimeter, are explained by the fact that analyses are made about every three hours, while calorimeter readings are taken almost continuously during the day. The number of observations is therefore much greater for the latter than for the former. For all calculations the heat values determined by calorimeter are used exclusively. The methods of gas sampling and analysis used as described by Mr. L. A. Touzalin are as follows:

Daily samples of blast furnace gas are taken at each individual furnace, all samples being accumulative and representing a fair average of the gas production extending over a period of 24 hours. The sample is taken between down comerstand pipe and dust catcher (as shown in Fig. 5) and conducted by means of a $2\frac{1}{2}$-in. or 2-in. pipe, first to a miniature dust catcher and then to two washing bottles connected in series by means of a 2-in. pipe. From the second bottle

the gas passes to a sampling tank of 5 cu. ft. capacity, made of galvanized iron and of regular gas-holder construction. All water used in the washing bottles and in the sampling tank is first saturated with blast furnace gas. The small dust catcher consists of an 18-in. length of 6-in. iron pipe capped at each end and suspended in a vertical position. By removing the cap at the bottom end, the accumulated dust may be cleaned out as often as necessary. The valve placed at the lower end permits a small stream of gas to flow continuously through the sampling pipe into the small dust catcher and escape into the air. A great deal of dust escapes with this gas, and besides preventing continuous clogging, this valve allows any condensed water to drain off. The screw cock attached to the rubber tube between the washing bottles affords means of so adjusting the rate of flow that the tank is almost filled in 24 hours. At the end of each period a sample of the accumulated gas in the tank is withdrawn into a glass gas holder of 250 cu. cm. capacity, while the remaining gas in the tank is allowed to escape into the air. The bell of the tank thus drops down in place and the gas is again started for the next 24-hour sample. The 250 cu. cm. sample of the gas in the gas holder is taken to the laboratory for analysis. At the power station, where a special gas laboratory, fully equipped, is installed, gas samples are taken directly from the gas main between gas holder and engines. Gas analyses are made several times during the day and as often as necessary if any unusual occurrences at the engines indicate a change in gas quality.

33 Daily gas analyses and heat values as well as results of dust and moisture determination, together with additional chemical information, are recorded on daily report sheets (Fig. 6).

DESCRIPTION OF GAS-CLEANING PLANT

34 When the installation of blast furnace gas engines was decided on in 1906, very little information and experience on the important matter of gas cleaning was available in this country. Some experiments had previously been made at the plant under discussion on a small scale, with different designs of wet scrubbers and baffle washers, the deception generally prevailing at that time that gas could be cleaned sufficiently for engine purposes by so-called "static" methods, that is, by passing it through towers filled with baffle plates and a checker work of wood or iron, and sprayed with water in finely divided form. The results of these experiments were discouraging, as might have been expected, and the installation of Theisen gas washers for refining the gas was eventually decided upon.

35 The blast furnace gas for the gas engines is cleaned in two distinct stages. It is first subjected to a preliminary dry and wet scrubbing in the so-called primary or preliminary cleaning plant, and subsequently undergoes a secondary cleaning or refining by Theisen washers in the secondary washing plant. Fig. 3 shows dia-

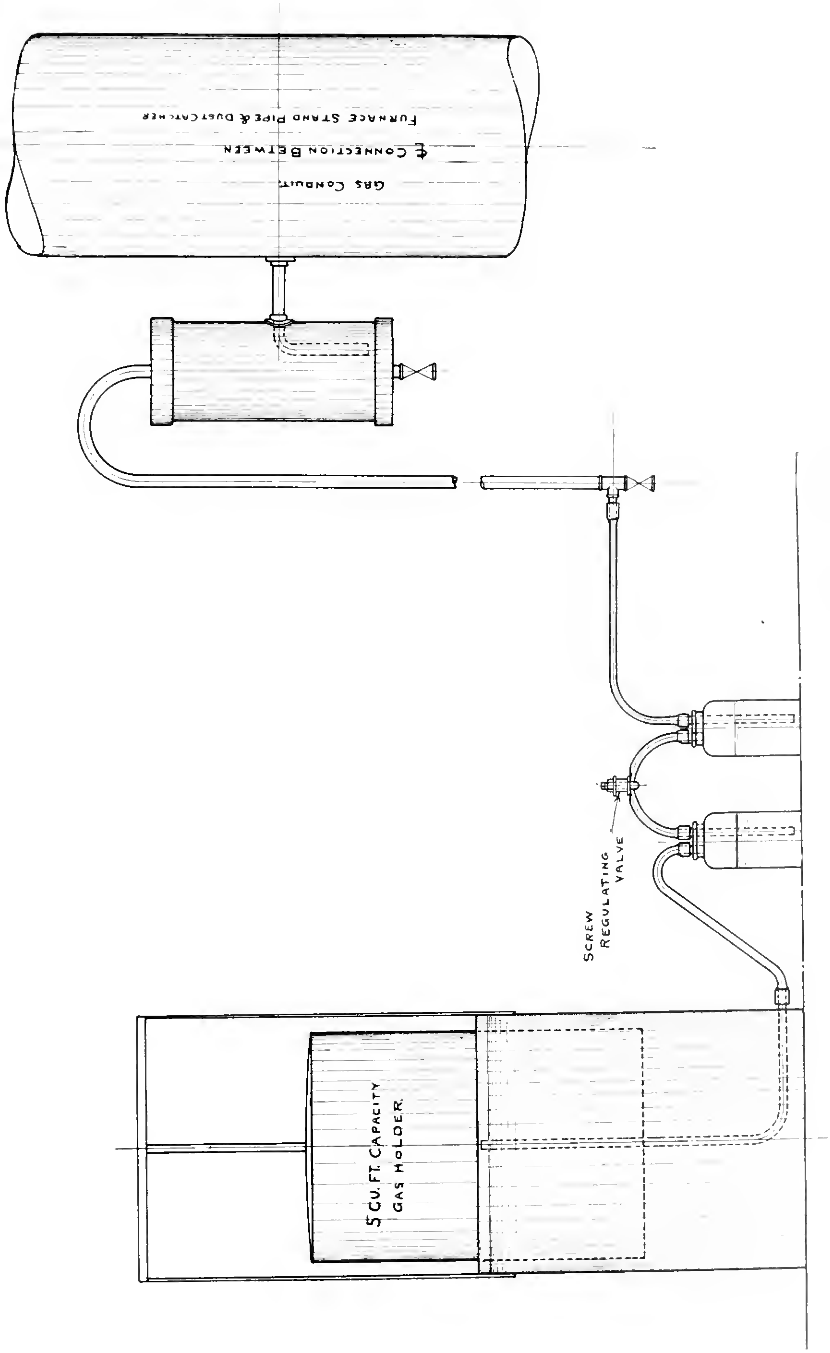


Fig. 5 Apparatus for Continuous Gas Sampling

DAILY CHEMICAL REPORT — For 24 Hours Ending 6 A.M. Tuesday, Sept., 21st

BLAST FURNACE GAS
Samples taken at Gas power station laboratory

TIME	CHEMICAL ANALYSIS By Volume CO_2	CO	H_2	CH_4	$\frac{CO_2}{CO}$	$\frac{CO}{CO_2}$	B.T.U. Per Cubic Foot By Analysis	By Junkers' Calorimeter
9.00 A.M.	8.1	31.1	3.6	.2	.260	3.84	112.6	112.0
9.30								111.9
10.00								111.0
10.30								121.2
11.00	8.2	32.2	3.7	.2	.255	3.92	116.5	119.9
11.30								116.2
12.00 NOON	8.2	32.2	3.0	.1	.255	3.92	113.6	114.0
12.30 P.M.								113.1
1.00								112.7
1.30								111.1
2.00								110.7
2.30								113.1
3.00								112.5
3.30								112.7
4.00	8.7	31.0	5.0	.1	.280	3.56	115.2	114.3
4.30								114.7
AVERAGE	8.3	31.6	3.8	.2	.262	3.81	114.5	113.8

		DAY TURN	NIGHT TURN	AVERAGE
Weather		Fair	Clear	–
Barometer		29.40″	29.31″	29.35″
Direction of Wind		Southwest		
Test Started		8.10 A.M.	5.00 P.M.	–
Test Ended		4.10 P.M.	8.00 A.M.	–
Number of cubic feet of gas passed through filter	Before Scrubbers	39.10	54.20	46.65
	After Scrubbers	59.22	100.63	79.92
	After Theisens	–	–	–
	A.C. Station Gas	88.36	118.37	118.37
	Blowing Eng. Gas	–	–	–
Moisture Grains per cu. foot	Before Scrubbers	–	–	–
	After Scrubbers	14.719	–	–
	After Theisens	–	–	–
	A.C. Station Gas	8.984	–	–
	Blowing Eng. Gas	–	–	–
	In Air	6.49	6.15	6.32
Flue Dust Grains per cu. foot	Before Scrubbers	3.8830	4.0812	3.9821
	After Scrubbers	.8147	.6884	.7516
	After Theisens	–	–	–
	In A.C. Engine Gas	.0085	.0052	.0068
	In Blowing Eng. Gas	–	–	–
% Dust Removed-Scrubbers		79.0	83.1	81.0
% Dust Removed-Theisens		98.9	99.2	99.0

Note-All figures given on this report are reduced to standard conditions i.e.
Temperature 62°F, Barometer 30″ Mercury
The heat value Constants are;
CO --- 324.45 B.T.U. PER CUBIC FOOT
H_2 --- 274.78 " " "
CH_4 -- 916.08 " " "

Metric Conversion Factor
1 Gram-15.43 Grains
MacFarland's tables of Reduction
Factors are used for all calculations within their scope.

OBSERVATIONS-
Furnace 1 on Ferrosilicon.
" 2 Basic iron.
" 3 " "
" 4 " "
" 5 Bessemer iron.
" 6 " "

3 Gas engines in operation.

Wm. Brady. CHIEF CHEMIST
Peterson.

Fig. 6 Form for Daily Chemical Report

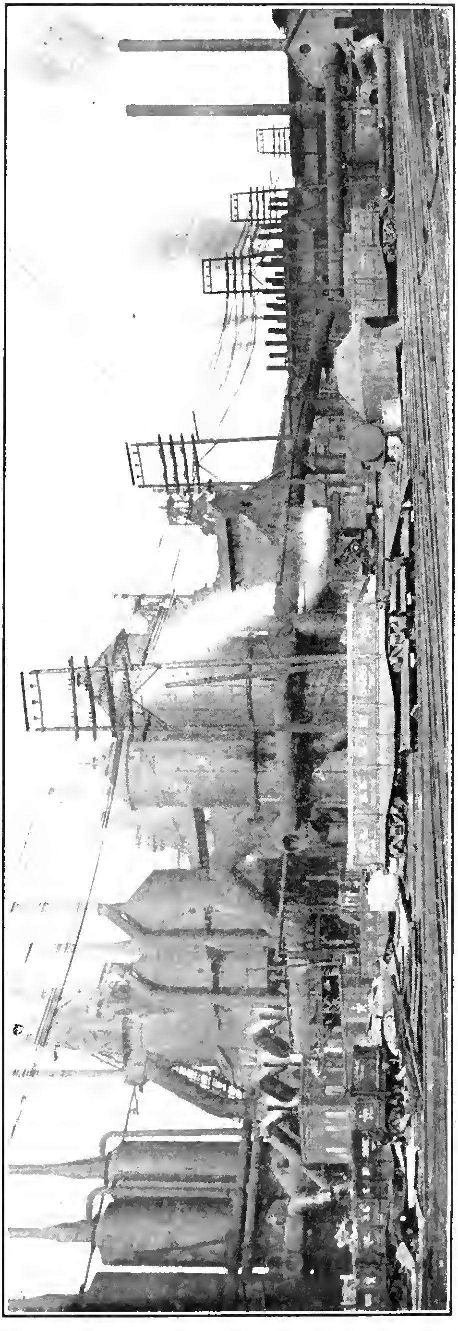


Fig. 7 General View of Gas-Cleaning Plant, 1908

grammatically the general arrangement of the complete cleaning plant as it existed in 1908, while Fig. 7 gives a photographic view. When the gas-cleaning plant was designed in 1906, the raw gas was not cleaned except by the usual small dry dust catchers at the end of the downcomers of each furnace, and it was decided to install two special dry dust catchers of large capacity to remove the bulk of the heavy dust.

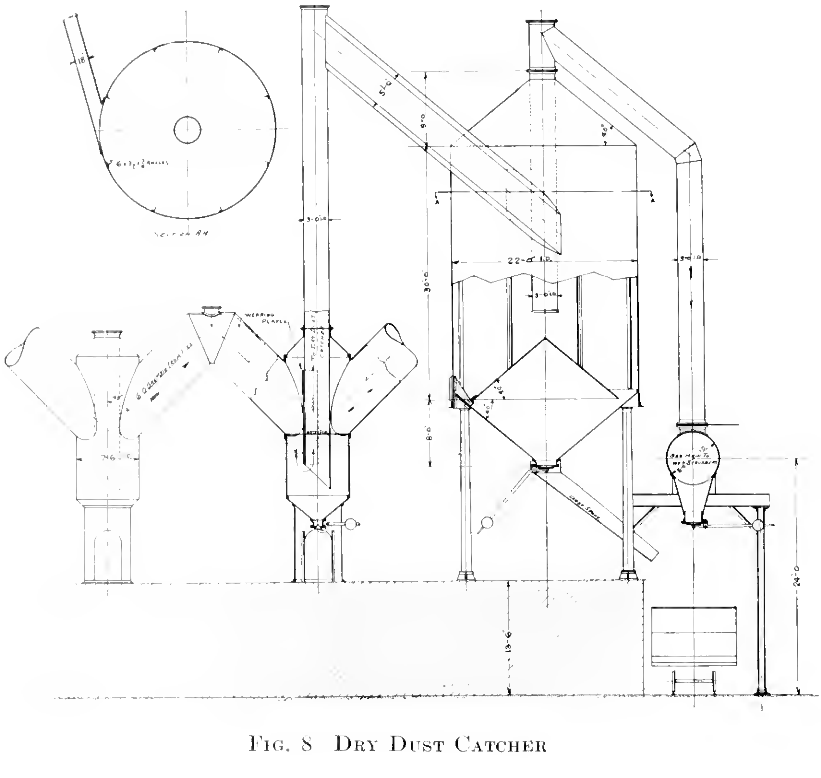


FIG. 8 DRY DUST CATCHER

PRELIMINARY GAS-CLEANING PLANT

36 The raw gas on leaving the overhead gas flue first passes a water seal serving to shut off the gas power plant from the general system in case of necessity, and enters an unlined self-cleaning zigzag gas flue 6 ft. in diameter. Fig. 8 shows in detail the plan, and Fig. 9 a photograph of the zigzag flue and the dry dust catchers. It was originally intended to increase the capacity of the preliminary cleaning plant subsequently, by the addition of enough dry and wet scrubbers to clean the total quantity of gas produced by all six furnaces, for use

under boilers and in hot blast stoves, and provision for these additions was made when designing the cleaning plant. By means of water seals in the "dust legs" supporting the zigzag flue, and spectacle valves at the points of discharge of the dry-dust catchers into the "collecting main," each dust catcher may be shut off during the operation of the plant, in case of repairs or cleaning. As seen in the illustrations these water seals were designed on the principle of the Crawford valve, and by cutting off the ends of the inside pipes at an angle, it was intended to provide means of regulating the amount of gas passing through each dry dust catcher by filling the seal with water to a certain height, which was regulated by telescopic overflow.

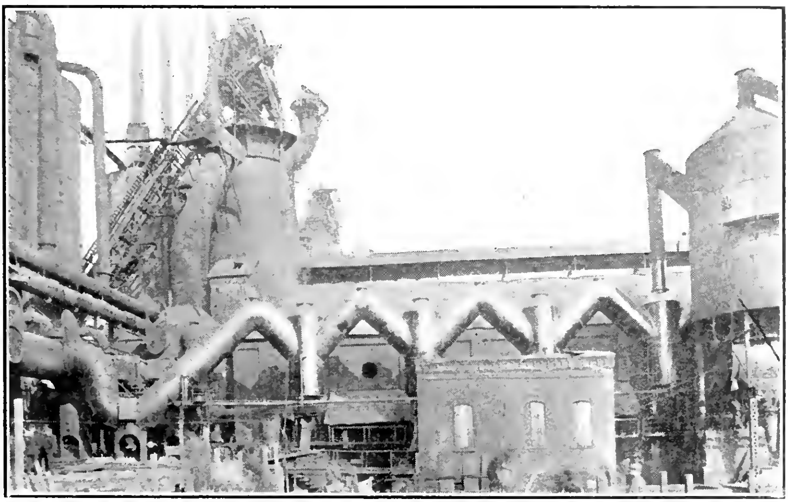


Fig. 9 Zigzag Main and Dry Dust Catcher

37 Neither zigzag main nor dry dust catchers were lined with fire brick, as had heretofore been the practice with all gas pipes conveying raw gas of high temperature, as it was desired to take advantage of the reduction of temperature by radiation of heat through the unlined plate work. The results given elsewhere prove that the desired object was very satisfactorily accomplished. At all points of sudden change in direction of the flow of gas, "wearing" plates were provided, as excessive wear of the plate work, from the impinging of the dust-laden gas, was expected. These plates can be removed and replaced by new ones, through manholes arranged for this purpose. The dust

legs, as well as the dry dust catchers, were raised above the yard level high enough to permit the disposition by gravity of the accumulated flue dust into railroad cars by means of bell valves and dust spouts.

38 The dry dust catchers, two in number and operating in parallel, were 22 ft. in diameter by 31 ft. high with 9-ft. cones at each end. The choice of the diameter of the dry dust catchers, as well as of the

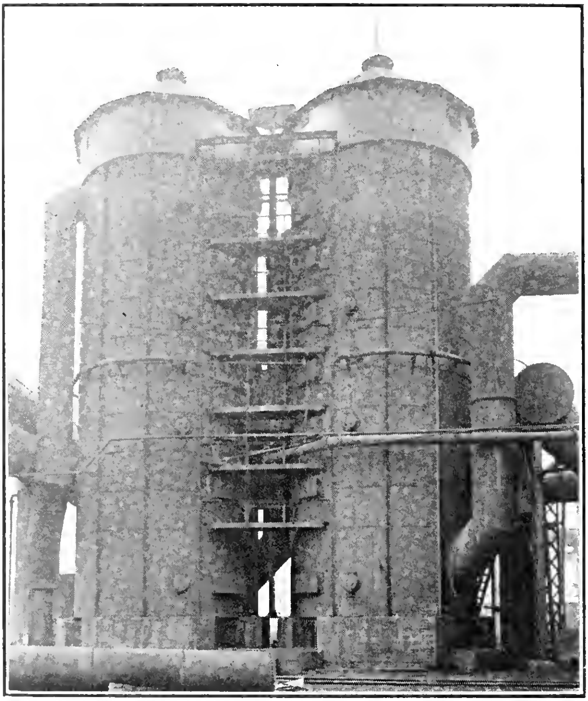


FIG. 10 WET SCRUBBERS

wet scrubbers, was accidental, as it happened that some old 22-ft. hot blast stove shells were available at the time. The dry dust catchers were given tangential gas inlets, assuming that by this arrangement, and by inclining the flattened gas-inlet pipe, the gas would be caused to travel in long spirals from top to bottom, thus lengthening the path of the gas, and angle irons were placed vertically on the inside of the shell to provide for increased friction while the gas was traveling through the dust catchers at the slow rate of 1.5 ft. per sec. The

bottom cone was separated from the cylindrical part of the dust catcher by an inverted cone arranged umbrella-wise to prevent the dust accumulated in the bottom cone from being stirred up by disturbances caused by furnace slipping and re-entering the gas. The gas left the dry dust catchers near the apex of the umbrella, passing through a self-cleaning pipe into the collecting main and hence to the wet scrubbers. Explosion doors were arranged for on the dry dust catchers, but were eventually bolted down as unnecessary.

39 From the 6-ft. 6-in. collecting main, the dry-cleaned gas passes to the wet scrubber, shown in Figs. 10, 11*a*, 11*b* and 11*c*, through self-cleaning pipe lines. The piping arrangement permits the operation of the original two wet scrubbers in series, or in parallel, by turning a number of spectacle valves, and water seals allow the shutting-off of either wet scrubber for cleaning, without interfering with the operation of the power plant. From the start the two wet scrubbers were operated in series, the total quantity of gas consumed by the engines passing first one and then the other. The gas enters each wet scrubber at the bottom of the shell, which is 22 ft. in diameter and 55 ft. in height. The inside is divided horizontally into six compartments, each containing eight rows of slats made of clear No. 1 white pine dressed all over. Each system of slats is supported independently by I-beams and angle irons riveted to the shell. The slats are 5 in. high and $\frac{7}{8}$ in. thick, by about 5 ft. 6 in. long, and ten slats on an average are nailed to distance pieces, forming hurdles about 5 ft. 6 in. long, and 3 ft. 7 in. wide, a size and weight which permit of easy handling. An

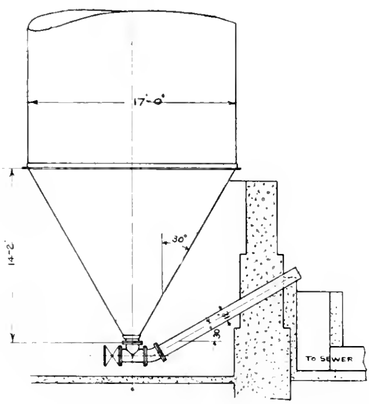


FIG. 11*a* DETAIL OF SCRUBBERS NOS. 1 AND 2

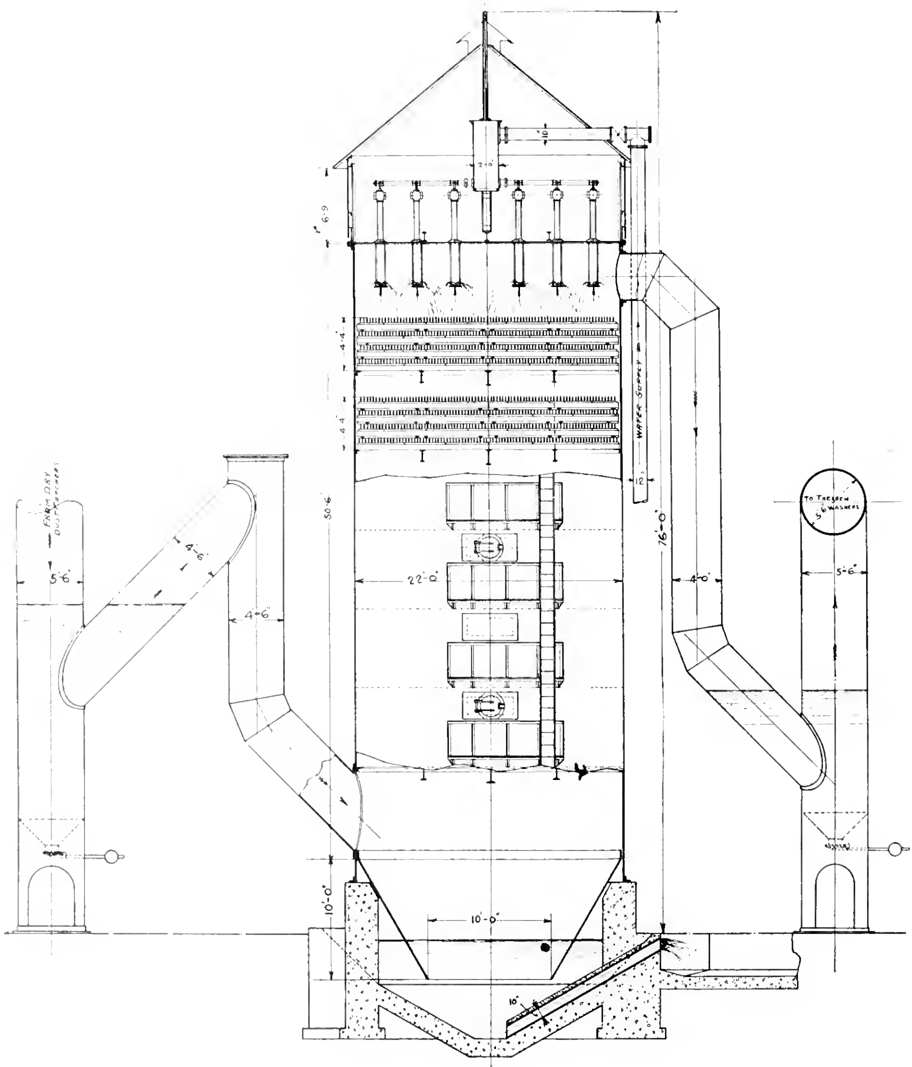
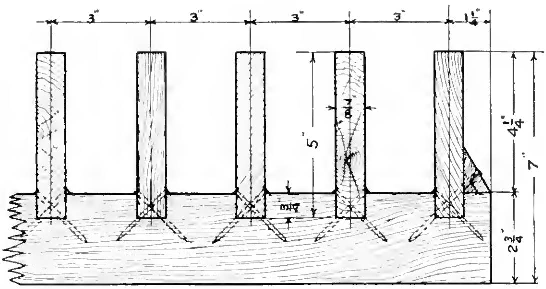


FIG. 11*b* SECTION OF SCRUBBERS NOS. 3 AND 4

interior view of the scrubbers with the hurdle arrangement is shown in Fig. 12.

40 Profiting by the experience gained elsewhere with wet scrubbers of the same kind, flue dust bridging over between slats and clogging the hurdles, it was decided to space the slats in the following manner;



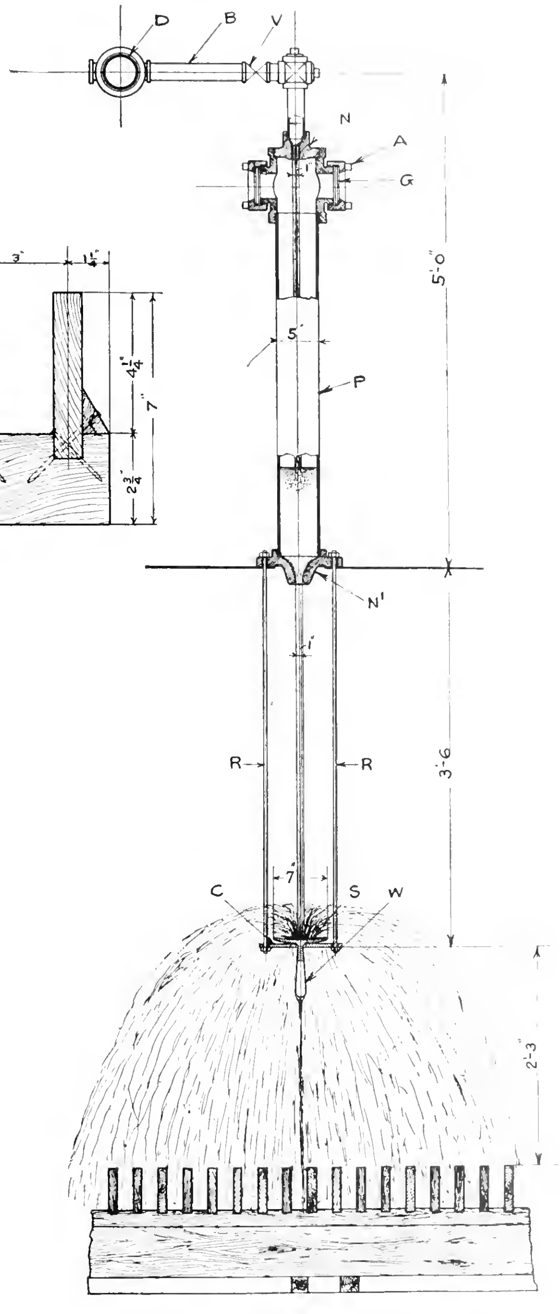


Fig. 11c Detail of Sprinklers and Hurdles

In the three lower compartments of scrubber No. 1, which receives dry-cleaned gas containing a large amount of coarse flue dust, the average distance of the slats was made 9 in. while in the three upper compartments the slats have 6 in. spacing. In the three lower compartments of scrubber No. 2, receiving gas already washed in the first scrubber, the slats were spaced with $4\frac{1}{4}$in. centers, while the corresponding distance is 3 in. in the three upper compartments of the second scrubber. All hurdles were placed in the different rows and compartments in such a way that the slats of each upper row straddle the slats of the row immediately below, thus obtaining a continuous

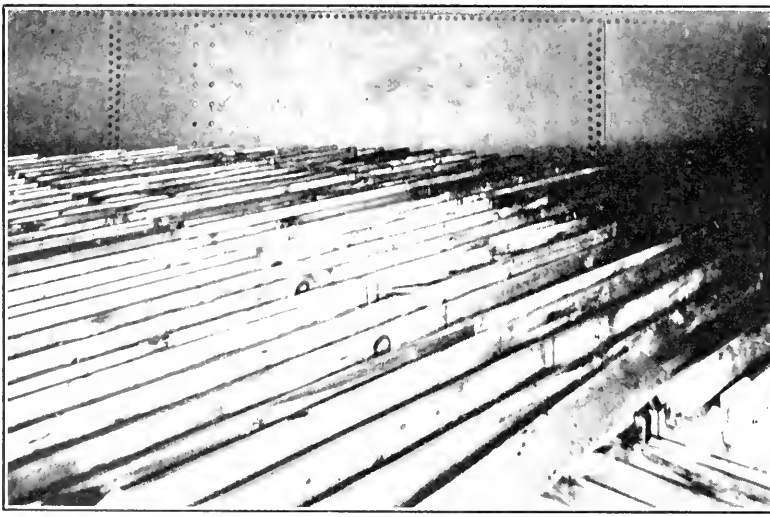


FIG. 12 INTERIOR VIEW OF SCRUBBERS SHOWING HURDLES

checker arrangement without any channels. A space of about two feet was left between each two hurdle sets, making each compartment accessible for cleaning or changing hurdles without removing the whole filling, and manholes and platforms were provided to facilitate this work.

41 The top of the wet scrubbers is formed by $\frac{5}{16}$ in. flat covers, supported by 8-in. I-beams. Each cover plate supports 36 sprinklers, shown in Fig. 13 and in detail in Fig. 11*c*, distributed over the entire section. Each sprinkler consists of two nozzles N and N', and a cast-iron spray plate S with slightly curved surface and weight W

to insure horizontal position. The spray plate is inserted in the center hole of the crosspiece C, which is supported by two rods R fastened to the top cover plate. The upper nozzle of 1 in. diameter is mounted on one branch of a cast-iron cross, while the opposite branch is connected by a 5-in. wrought-iron pipe P about three feet in length, to the lower nozzle N' of equal size. The other two branches of each cross are closed by caps A, containing plate glass discs G, $\frac{1}{4}$ in. thick and 4 in. in diameter. The open water tank located above the wet scrubber supplies the washing water under a small but constant head, through distributing pipes D and branch connections B to the sprinklers, the amount of water being regulated by valves V. The operation of these sprinklers is obvious. A stream of water falls in each sprinkler through a distance of about eight feet, breaking up into an exceedingly fine mist by impinging on the spray plates, and as the sprays of the 36 sprinklers overlap each other, the distribution of water is perfect.

42 These sprinklers were tested before the wet scrubbers were put into operation, and one minute after turning on the water there was not a dry spot on the inside of the scrubbers. Originally these sprinklers were without the nozzle N'. The action was the same as far as the distribution and the atomization of the water was concerned, but with the serious drawback that the dirty gas could reach the upper part of the sprinklers and deposit dirt on the sight glasses, which soon became useless. By the insertion of nozzle N' this trouble was successfully overcome, as the water flowing through this nozzle completely seals the upper part of the sprinklers so that the glasses can be removed during operation without danger from escaping gas. The great advantages of this type of sprinkler are that a clogging of the water passages can never occur, and uniform distribution of the water can always be obtained. Their operation has been exceedingly satisfactory. All water piping on top of the wet scrubbers is housed-in for protection against frost.

43 The lower part of the wet scrubbers dips with a conical extension into a water seal provided in the concrete foundation. The muddy water is carried off through an overflow pipe reaching to the bottom of the seal, thus keeping the water in constant circulation and thereby effectively preventing any accumulation of mud in the seal. It was found advantageous, however, to introduce into this overflow passage and reaching to the bottom of the seal, a 1-in. pipe through which water under pressure is constantly discharged, stirring up the

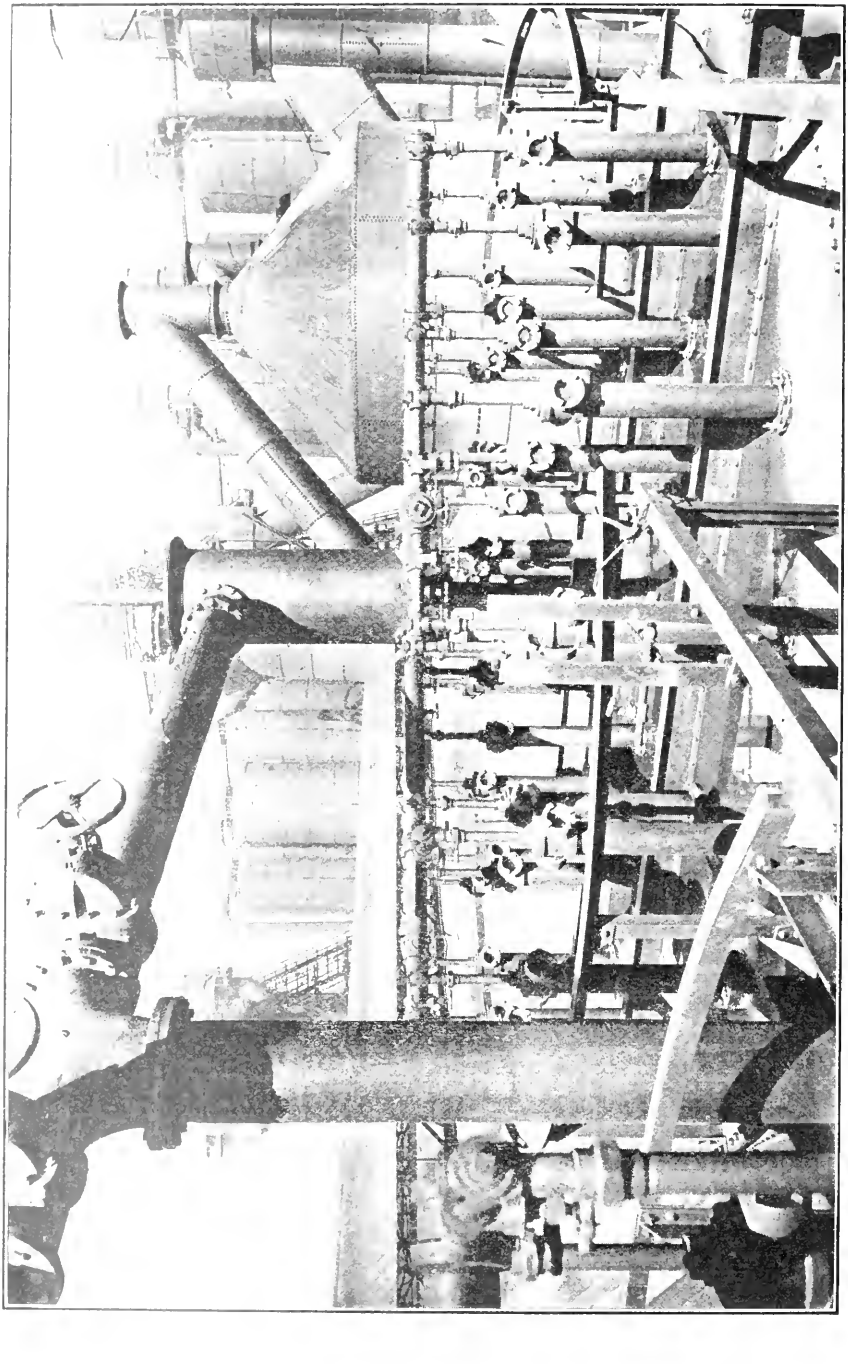


Fig. 13 Water Sprinklers

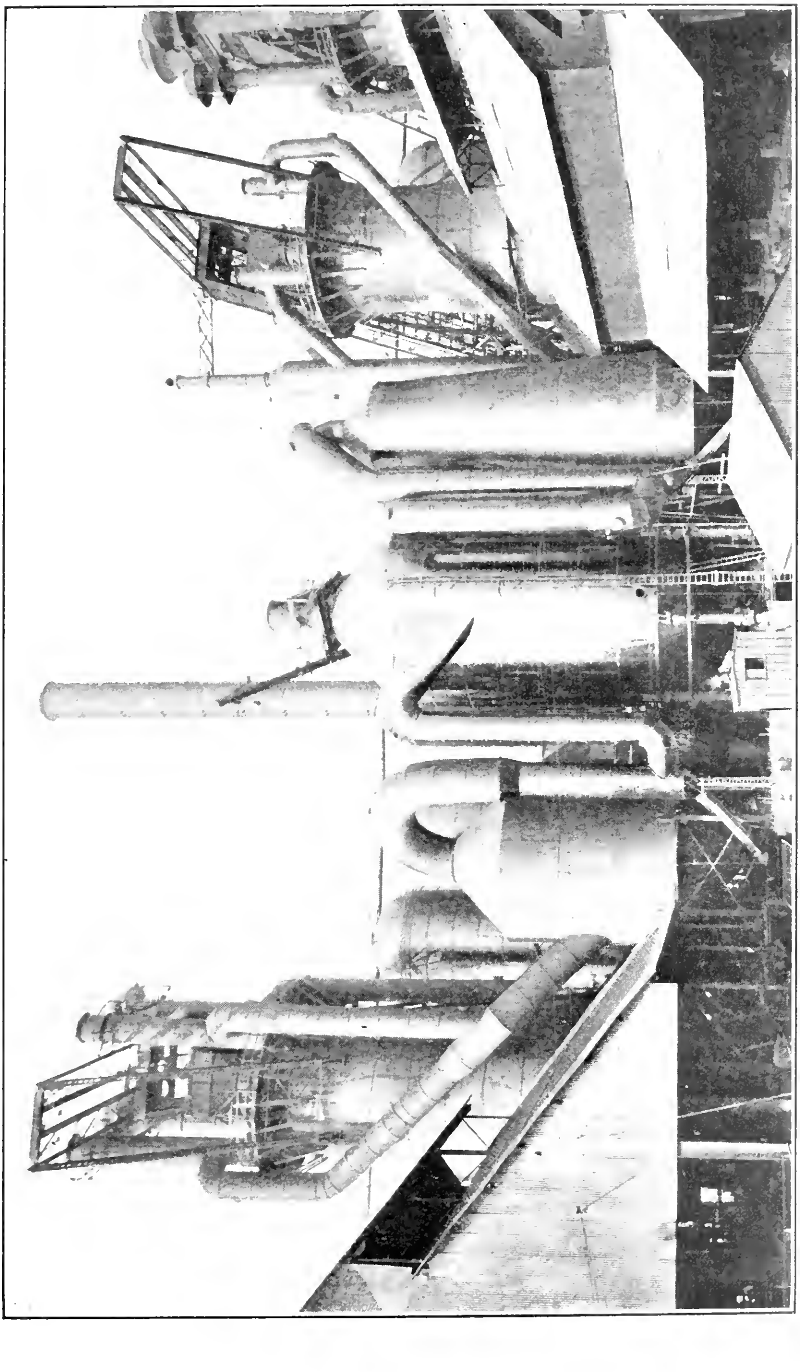


FIG. 14 DRY DUST-CATCHER SYSTEM AT FURNACES 5 AND 6

sediment and keeping the water in motion. On the two new wet scrubbers recently installed this type of water seal was abandoned in favor of the simple arrangement shown in Fig. 11*b*.

44 The waste water from these scrubbers flows into a large settling tank, which was installed to prevent a possible clogging of the main sewer. Both compartments of the settling tank, which was in operation about two years, have since been completely filled with mud, but as the dust in suspension does not prove to be troublesome in the sewers, little attention is being paid to their regular cleaning.

45 When in the early part of 1909 four additional gas blowing-engines for blast furnaces No. 1 to 4 were purchased, an increase in the capacity of the gas-cleaning plant was necessary, and since in the meantime the question of dry cleaning the raw gas at the furnaces had been solved, it was decided to change the two original dry dust catchers into wet scrubbers. As soon as the voluminous dry dust catcher system at the furnaces (Fig. 14) was in operation its effect was noticed in the materially reduced efficiency of the dry dust catchers in the preliminary gas-cleaning plant. These had formerly removed a great deal of heavy, dry flue dust, but suddenly became practically useless, and only a little dust, now in the form of mud, was taken out. While the change from dry dust catchers to wet scrubbers was being made, in the second half of 1909, only the two original wet scrubbers were in operation. In the near future four wet scrubbers, of sufficient capacity to take care of the preliminary washing of the gas required by 40,000 h.p. in gas engines, will be in use. Fig. 15 shows the general arrangement of the gas power installations at present. Fig. 16 is a diagram of the path of the gas through the new wet scrubbing plant, showing the combinations in which the four scrubbers can be operated. Fig. 7 shows the gas main carrying the clean gas from the wet scrubbers to the secondary cleaning plant. Attention is called to the design of the supports of this pipe line, which are built as so-called dust legs, wherein water and flue dust are deposited, and drawn off occasionally through bell valves. The clean gas main, while not self-cleaning, is arranged to slope in both directions. At certain intervals circular water pipes with spray arrangements are installed for flushing the clean gas main, and at the points where a sudden change of direction of the gas occurs sealed holes are provided, through which a thorough cleaning of the pipe line can be made, with fire hose and high-pressure water, during the operation of the plant.

46 After leaving the wet scrubbers, the clean gas, as it is called, is in such a condition that it could be used under boilers and in hot blast

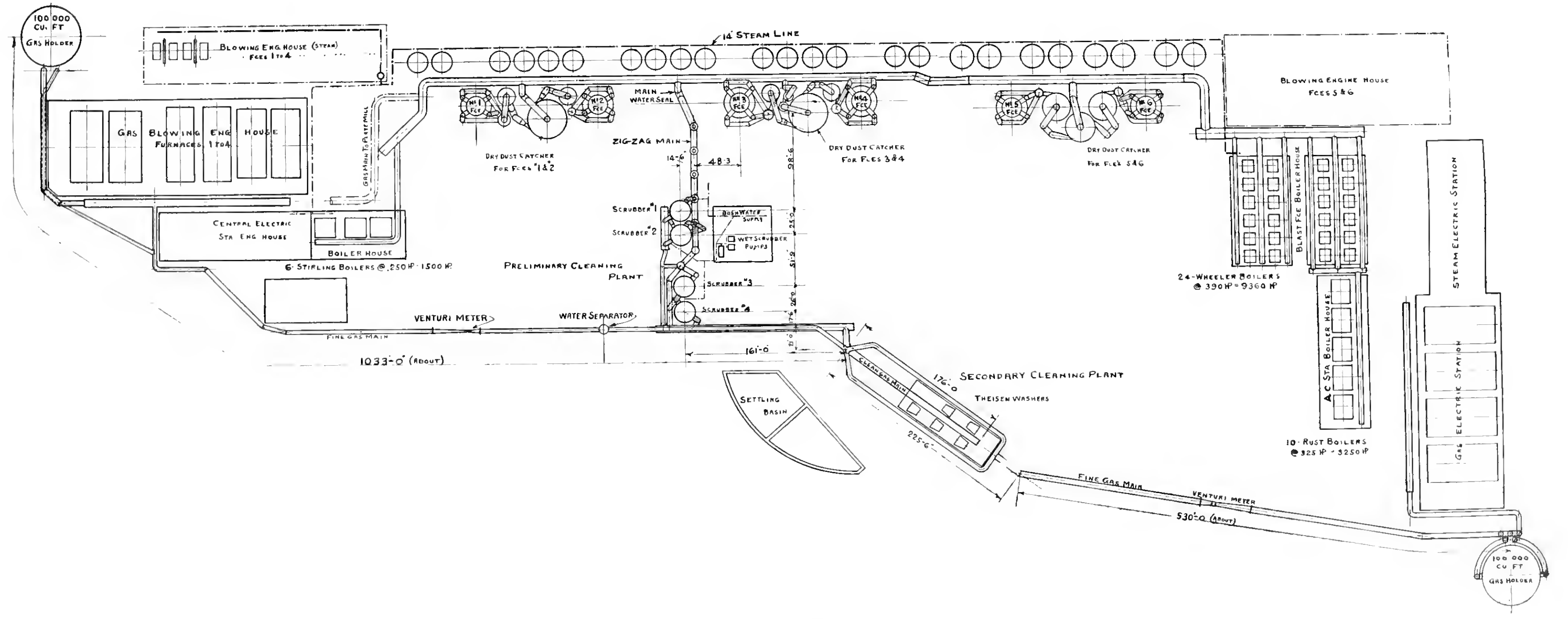


Fig. 15 Arrangement of Gas Power Plant 1910

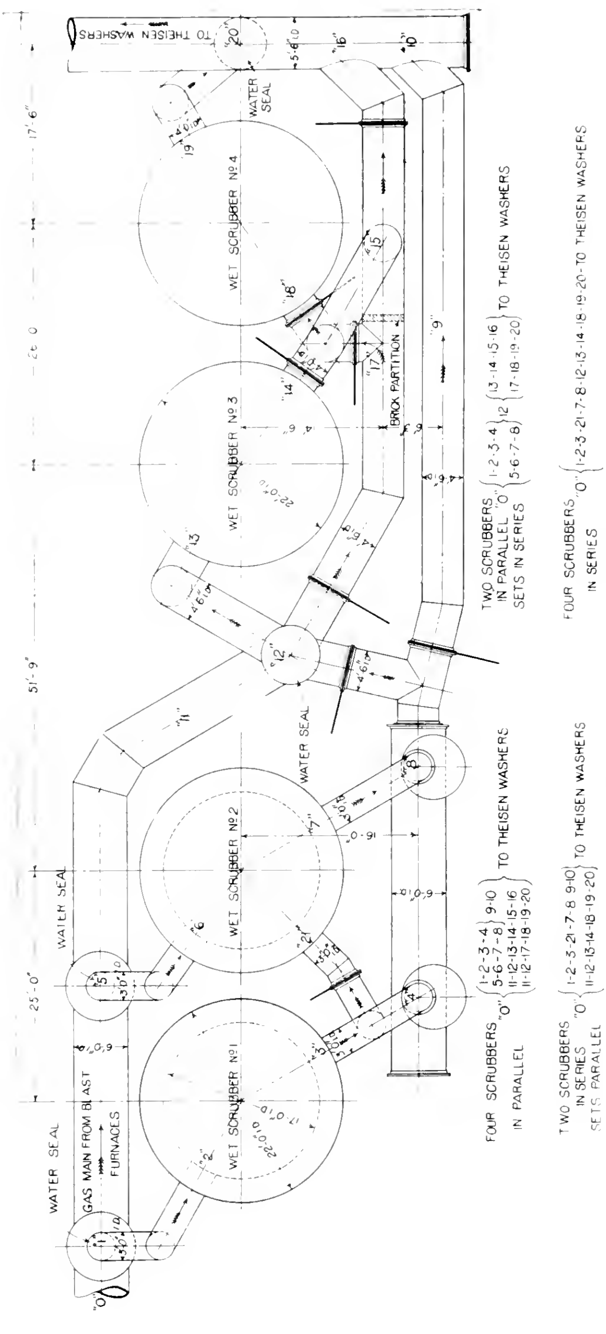


Fig. 16 Flow of Gas Through Wet Scrubbers

stoves, if desired. In 1909 it contained an average of not more than 0.318 grains of dust and not over 5.62 grains of moisture per cubic foot. Its purity therefore nearly complied with the requirements of European blast furnace plants where 0.5 grammes per cubic meter (0.218 grains per cu. ft.) is considered a desirable degree of cleanliness for stove and boiler gas.

IMPORTANCE OF GAS-CLEANING

47 Clean gas as delivered by the preliminary washing plant is, however, not sufficiently purified for gas engine purposes. Not so very many years ago it was thought in good faith that gas engines could operate on dirty gas, and it required years of costly experimenting to develop the art of gas purification to its present perfection, after the far-reaching importance of the problem was at last understood. Its magnitude can be better appreciated if the total quantities of gas and dust which are handled in such a cleaning plant during a certain period of time are considered. The following figures apply to the gas power plant under discussion for the year 1909.

48 The total number of kilowatt-hours generated by the gas engine installation was 50,494,100. The average heat consumption per kilowatt-hour was 17,234 B.t.u. The average heat value of the gas by calorimeter was 98.3 B.t.u. per cu. ft. The gas engines consumed therefore per kilowatt-hour 175.3 cu. ft. of gas, or in the year 1909 a total of 8,851,615,730, or nearly 9,000,000,000 cu. ft. This total quantity of gas reached the wet scrubbing plant containing on an average 1.533 grains of dust per cubic foot. There were consequently carried into the wet scrubbers during the whole year 1,938,500 lb. or 865 gross tons, of flue dust. To appreciate fully the meaning of this enormous figure it may be remembered that to haul this quantity away, a freight train of twenty gondola cars of 100,000 lb. capacity would be required. The average amount of dust in the clean gas for the year was 0.3183 gr. per cu. ft.; so that it carried 402,500 lb., or 180 gross tons of flue dust into the secondary cleaning plant. The difference of 685 tons was taken out by the wet scrubbers and carried off into the settling tanks. Expressed in per cent of the original quantity of dust, the wet scrubbers removed 80 per cent of the impurities. The Theisen gas washers further took out from the gas 176.7 tons, leaving only 3.3 tons in the fine gas, since the average amount of dust in the latter was 0.00583 grains per cu. ft. The Theisen washers had therefore an efficiency of 98 per cent, shared by clean gas main, fine gas main and gas holder.

The over-all efficiency of wet scrubbing and secondary cleaning plants was 99.5 per cent, since of the original 865 tons 861.7 tons was removed from the gas and only 3.3 tons entered the gas engines. Of the latter quantity only a small amount remained in the engine cylinders, since the bulk of the dust is swept into the atmosphere at each exhaust stroke. These figures will give a good idea of what it would mean if gas engines were operated on clean gas, not to speak of dry-cleaned gas, and yet this was attempted in the early history of the blast furnace gas engine.

SECONDARY CLEANING PLANT

49 It is generally recognized that blast furnace gas cannot be cleaned sufficiently for engine purposes without the expenditure of power, and that a satisfactory refining can only be performed in rotary gas washers on the "dynamic" principle, in contradistinction to the preliminary washing for which "static" methods are usually found to be fully adequate. Among the rotary gas washer systems on the market, the Theisen washer is considered to be mechanically well designed and very efficient. The Theisen washer installation consisted in 1909 of four washers, each of 15,000 cu. ft. per min. capacity. One additional washer has been installed recently on account of the new gas blowing-engines. Fig. 17 is an interior view of the Theisen washer building, and Fig. 18 shows the plan and elevation of this installation. The Theisen washers are arranged in two rows in a fireproof building, with the clean gas main overhead between them, and inlet pipes to the suction end of each washer. The outlet pipes pass through the building to water separators and to a ring main which delivers the gas through a 5 ft. fine gas main about 500 ft. long to the power station gas holder, and through a 4 ft. 6 in. fine gas main about 1,000 ft. long to the blowing-engine gas holder.

50 The Theisen washer, shown in sectional view in Fig. 19, consists essentially of a closed drum fitted on its outer surface with longitudinal blades arranged in spirals. This drum, supported by a shaft in two water-cooled ring-oiling bearings, rotates at high speed inside of a stationary casing of conical shape. The inlet end is equipped with suction vanes while on the discharge end an exhaust fan is firmly attached to the drum. The gas is introduced into the annular space between revolving drum and conical casing and discharged by the fan into a water separator. The operation of the washer is as follows:

51 The suction vanes draw the gas from the inlet pipe and deliver it to the longitudinal vanes, which have an inclination to the axis of

the drum so as to oppose the flow of the gas through the washer. The discharge fan at the outlet end of the drum, however overcomes this tendency and discharges the gas under positive pressure of a few inches of water. The clearance between the outer edge of the longitudinal blades and the inner surface of the stationary casing is not more than 1 in. and the gas passing through this narrow space under high pressure imparts to the water introduced at several points into the casing a movement in long spirals in an opposite direction to its own travel. This flow of water in the form of a film covering the inner surface of the stationary casing, is assisted by the conical shape of the latter, taper-

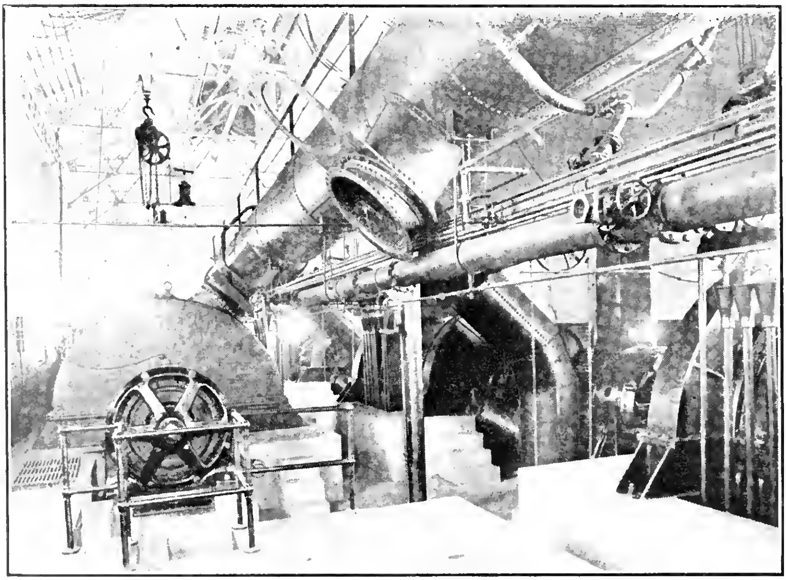


Fig. 17 Interior View of Theisen Washer Building

ing off towards the gas inlet. The surface of contact between gas and water is materially increased by wire netting, closely fitting the inside of the casing. By the intimate action of the water on the gas the dust particles are thoroughly moistened, and being weighed down by water drops, are thrown by centrifugal force into the rotating film of water, to be carried away through a seal into the sewer. The gas leaving the washer is charged with more or less moisture in the form of mist, which is removed from the gas in the Theisen washer separator, consisting principally of a removable box filled with iron shavings held in place

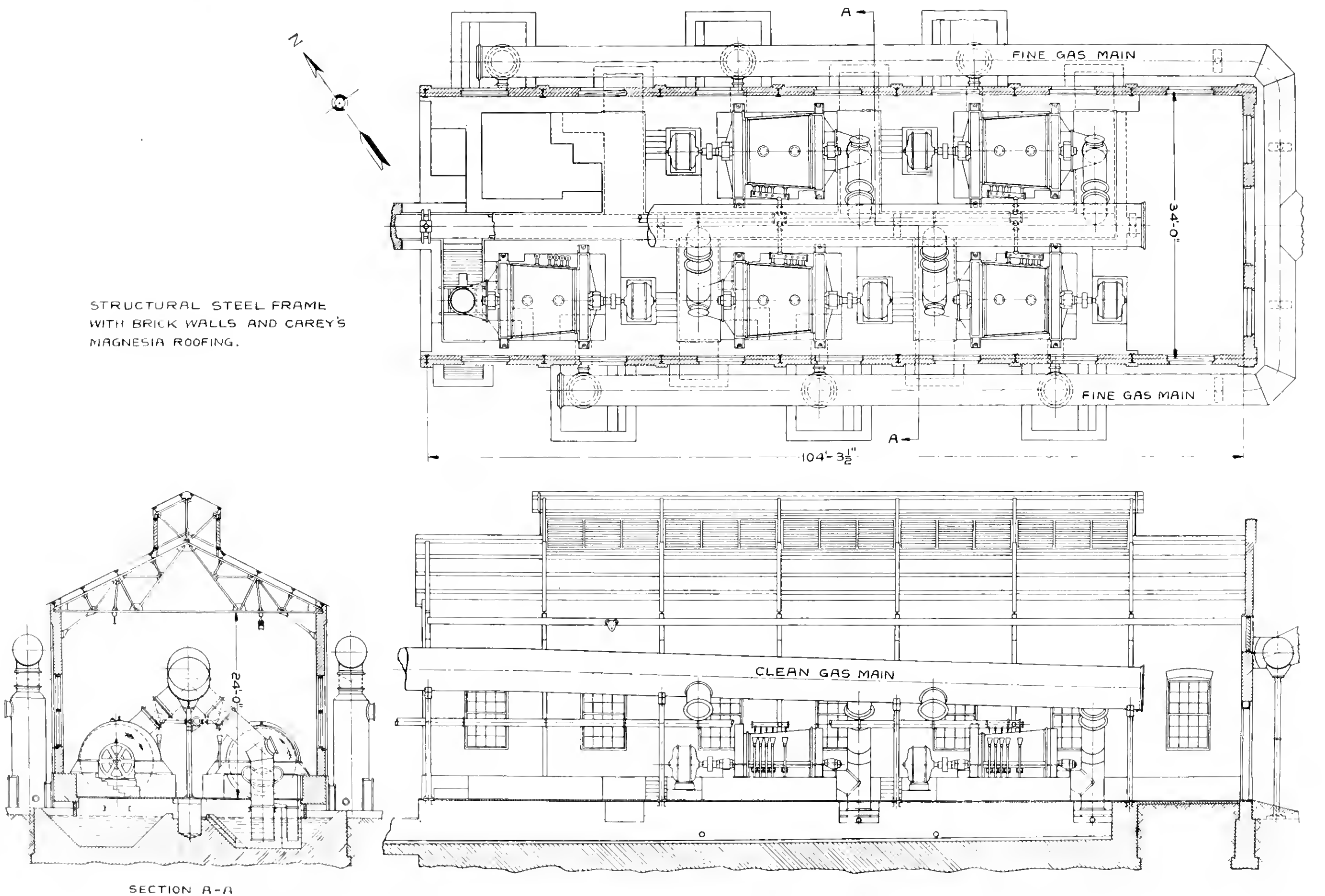


Fig. 18 Plan and Elevation of Theisen Washer Installation

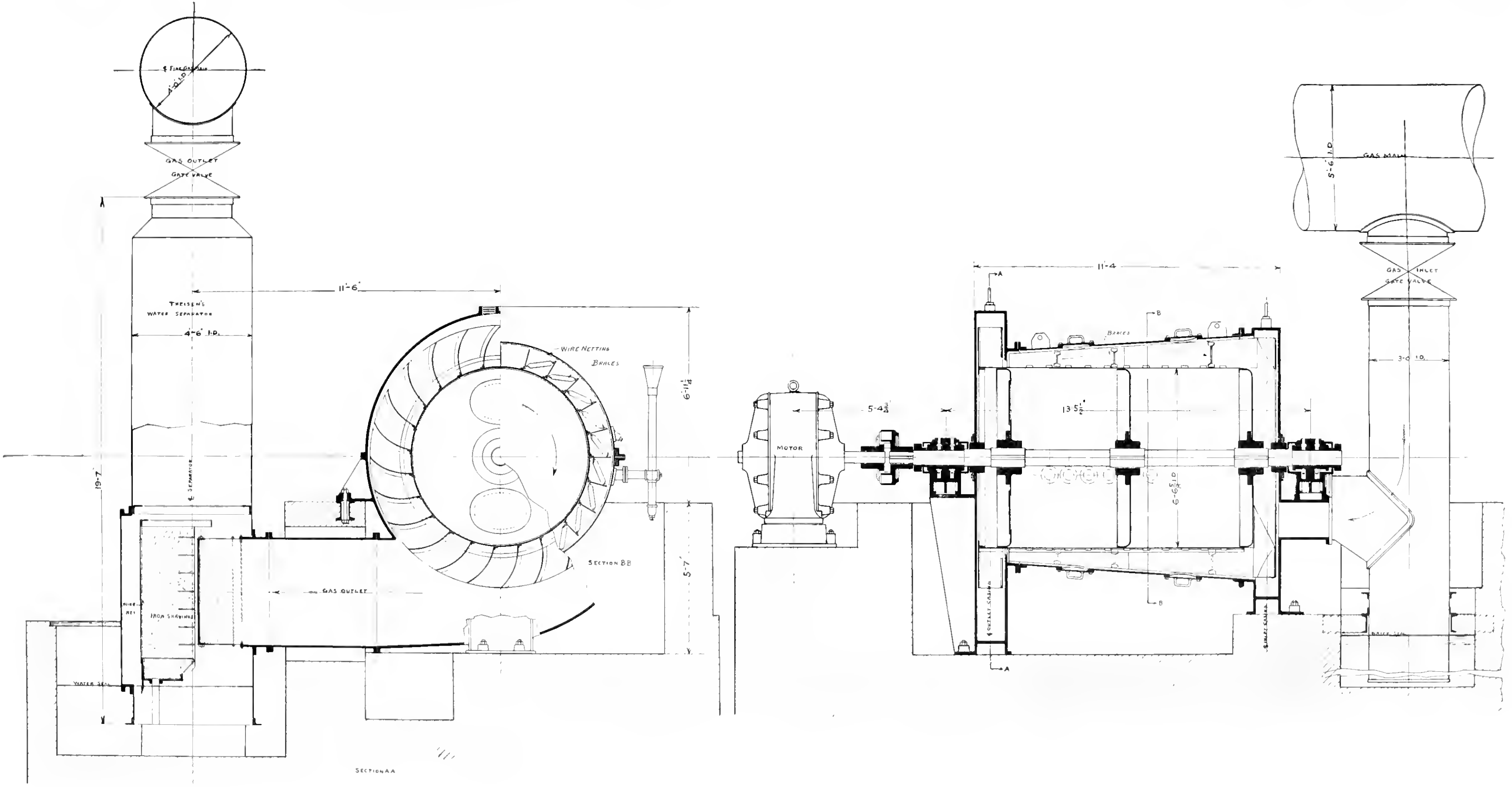


Fig. 19 Sectional View of Theisen Washer

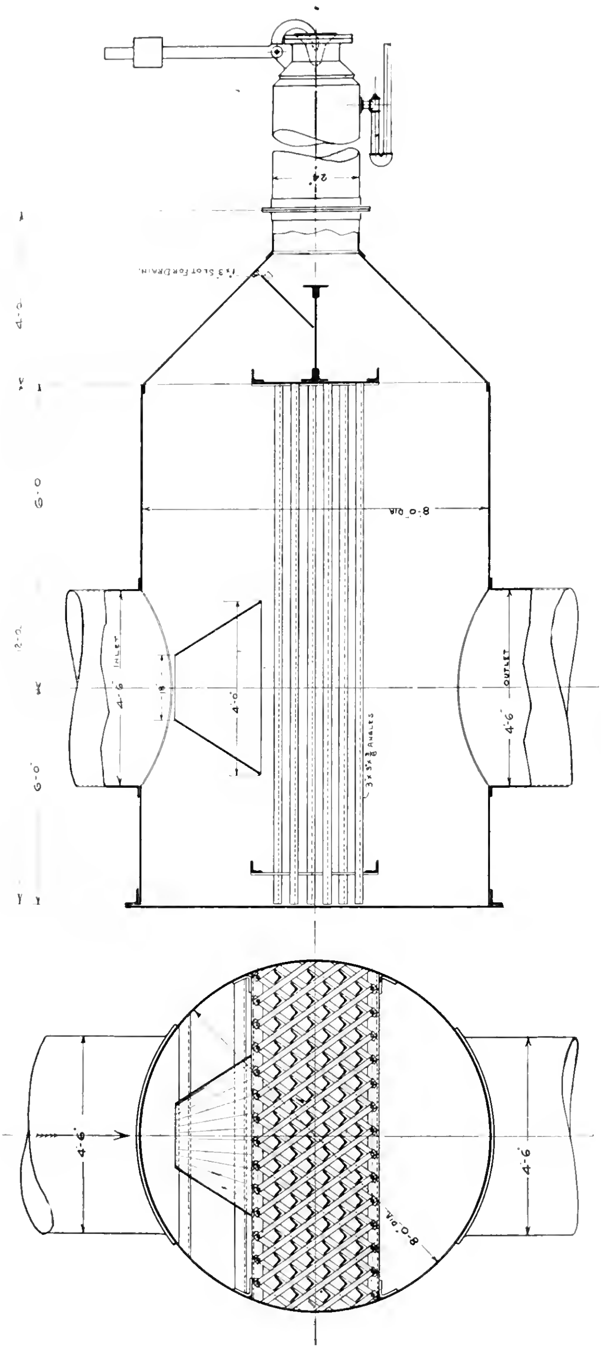


FIG. 20 WATER SEPARATOR

by wire netting. The gas striking the iron shavings with great velocity deposits its moisture, and as it has to reverse its direction it cannot pick it up again, but leaves the separator in a comparatively dry condition. Gate valves serve for regulating the quantity of gas entering the different washers, and for shutting off any washer without interfering with the operation of the plant.

52 The two gas holders, of 100,000 cu. ft. capacity each, were installed primarily to give a constant pressure of about four inches of water column at the gas engine throttle. Incidentally, however, they serve as reservoirs and as water separators. Since a gas holder was originally not contemplated for the gas blowing-engine installation an additional water separator, shown in Fig. 20, was provided in the fine gas main to the gas blowing engine house, the design of which is based on a well-known principle. A number of angle irons serve as baffles, dividing the gas into a number of streams which are forced to change their direction several times while passing through the rows of angle irons. The latter are placed "straddling" similar to the wooden slats in the wet scrubbers. A bell valve at the end of a long pipe serves to remove the accumulated water. Each gas holder is of the single-lift type, with bell 59 ft. 6 in. in diameter by 36 ft. high. Both holders have separate gas inlet and outlet pipes to obtain continuous circulation in the holder and prevent the pocketing of stale gas. While in the power station holder this idea was carried out to the extent of having inlet and outlet pipes at opposite ends of one diameter, the blowing-engine gas holder has these pipes side by side, but with the inlet turned a little to impart to the gas a rotating motion. Inlet and outlet pipes can be used as water seals to shut off the gas holder in case of necessity. To prevent the possible collapse of the gas holder bell, in case the supply of gas should be interrupted and a vacuum created underneath the holder bell, a disc valve supported by chains from the holder crown is located exactly above the mouth of the outlet pipe as shown in Fig. 21. When the holder bell descends until it rests on its landing beams, this valve will close the outlet opening, preventing a vacuum under the bell.

53 The discharge pressure of the Theisen washers is about 8 in. higher than the pressure on the suction side, and as the latter is quite variable, the former will also vary within considerable limits. It is of course possible to regulate the pressure in the fine gas main by means of the gate valves arranged in the Theisen outlets; but since these pressure variations are almost continuous, the gate valves would have to be adjusted by the operators practically all the time, unless it

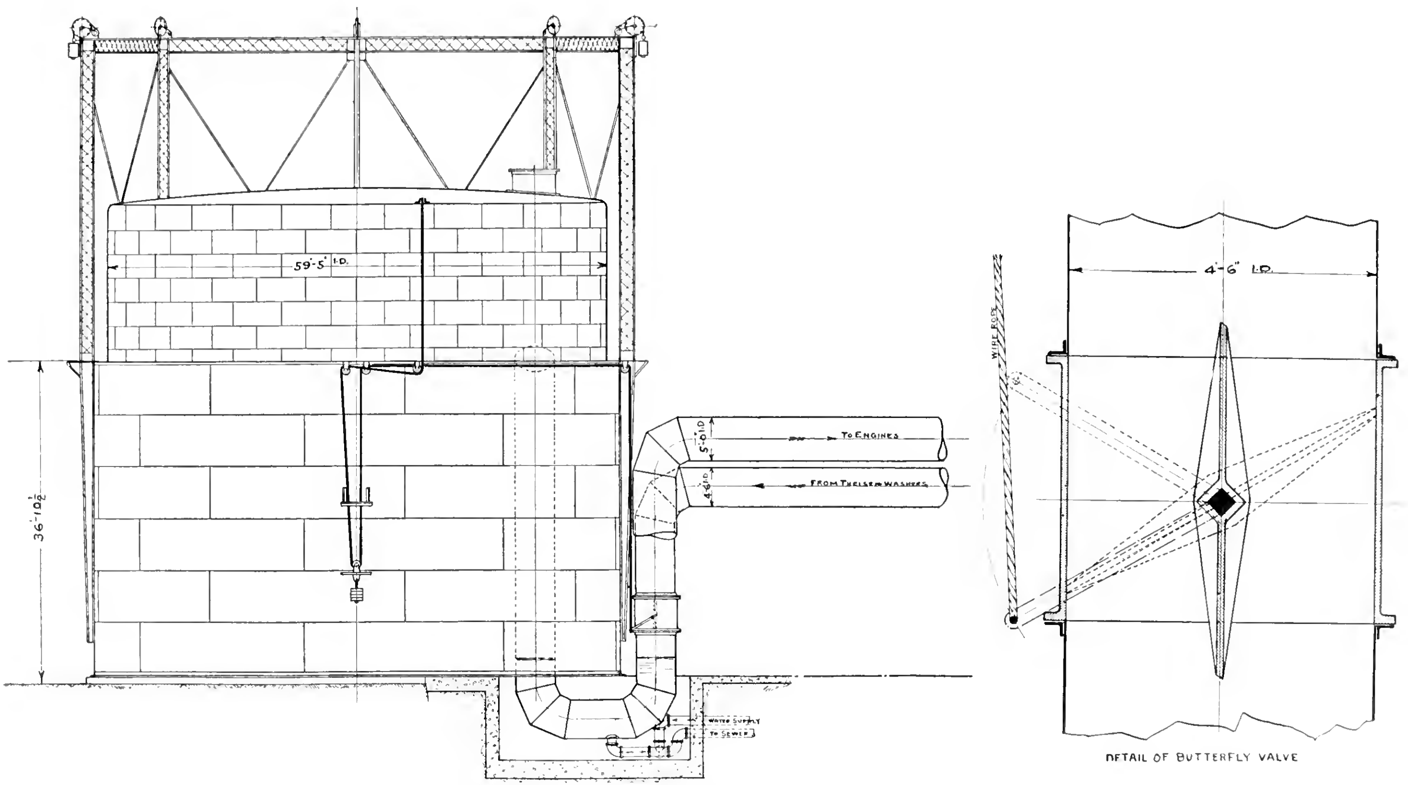


FIG. 21 GAS HOLDER AND AUTOMATIC BUTTERFLY VALVE

were desired to resort to the complication of electrically operated valves under automatic control of the gas pressure. To simplify this necessary regulation a butterfly valve was installed in the inlet pipe to each gas holder and operated by the holder bell itself by means of a wire cable fastened to it and carried over a system of pulleys as shown in Fig. 21. This device works in the following manner:

54 When the gas holder is empty, the butterfly valve is wide open and the counterweight hanger *H* with weights *W* is in its bottom position. When the bell ascends, hanger *H* rises without affecting the butterfly valve until bumper bracket *B* is reached, which prevents the further travel of the hanger. The movable pulley *P* now becomes stationary, and the rising holder bell acts through cable *C* on the butterfly valve, throttling and finally tightly closing it, the effect being precisely the same as if the gate valves on the Theisen washer outlets had been throttled or closed. The washers continue to operate, but cease to deliver until the descending gas holder bell again opens the butterfly valve. This action is perfectly automatic and it is impossible for more gas to enter the gas holder than is being taken out, so that any number of gas engines can be started or shut down at any time without the slightest adjustment at the Theisen washers.

55 Without this automatic regulator this is what would happen: The weight of the gas container gives a constant pressure of 4 in. of water column in the outlet pipe and the Theisen washers deliver a constant quantity of gas as long as the gas pressure on the suction side is constant. With a certain number of gas engines in operation, and the gas demand equal to the gas supply, the gas holder bell will float in a certain position. If, however, one or several engines are stopped, the gas demand will decrease and as the gas supply remains constant the bell will rise into its top position, determined by the height of the water seal in the holder tank. Any further rise will break this seal, causing gas to escape from underneath the holder bell. This will continue until more engines are started and the gas demand is again equal to the gas supply, or until the Theisen outlets are sufficiently throttled to reduce the quantity of gas delivered. The disadvantages are obvious. Not only will the breaking of the seal cause large quantities of water to be thrown out, but the escaping gas, aside from being unnecessarily wasted, will dangerously foul the surrounding atmosphere. The automatic butterfly valve, balancing perfectly the gas demand and the gas supply, eliminates these troubles very effectively.

56 A by-pass line permits the operation of the gas engines directly if for any reason the holder is out of commission. Each holder de-

livers the gas into a large main located on the outside of the gas engine buildings, as shown in Fig. 22. Individual branch pipes lead the gas to each engine, which can be isolated from the gas main by bell valves or water seals, as shown in Fig. 23*a*. The gas pipes leading to the engines, as well as all gas mains, are carefully drained by automatic overflows, an important feature.

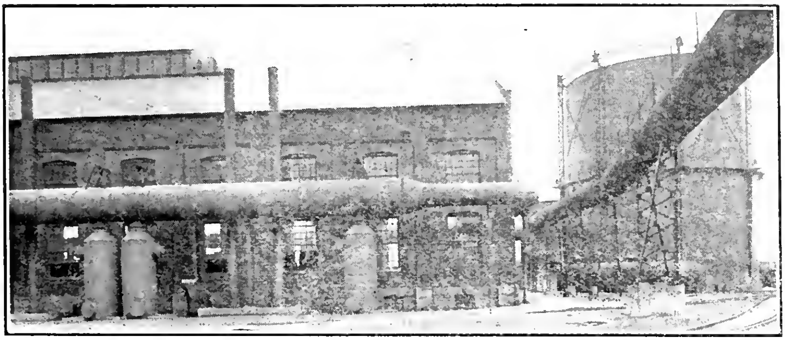


FIG. 22 EXTERIOR VIEW OF POWER HOUSE; GAS HOLDER AND GAS RECEIVERS

PERFORMANCE OF THE GAS-CLEANING PLANT

57 The physical qualities of the gas of importance from the standpoint of gas engine operation, are its pressure, temperature, dryness and cleanliness. These conditions, and particularly the last, if ascertained and suitably recorded at various stages of the cleaning process, are valuable indicators of the efficiency of the gas-cleaning plant; very few blast furnace plants, however, pay sufficient attention to their regular routine determination. As a rule tests are being made and results recorded only so long as the gas engine installation is new and therefore of all-absorbing interest. Particularly if the operation of the plant seems satisfactory, the interest is soon lost and the plant is left entirely to the care of the operating men, who soon are the only authorities on the machinery in their charge. The knowledge that can be obtained from them is of questionable value, as it is often based on good memory only, and gathered in hit-and-miss fashion. All operative results of a gas power plant should be recorded with as thorough care as is usually afforded the operation of steam plants, or even more, since the gas engine is more susceptible to variations in the quality of its fuel.

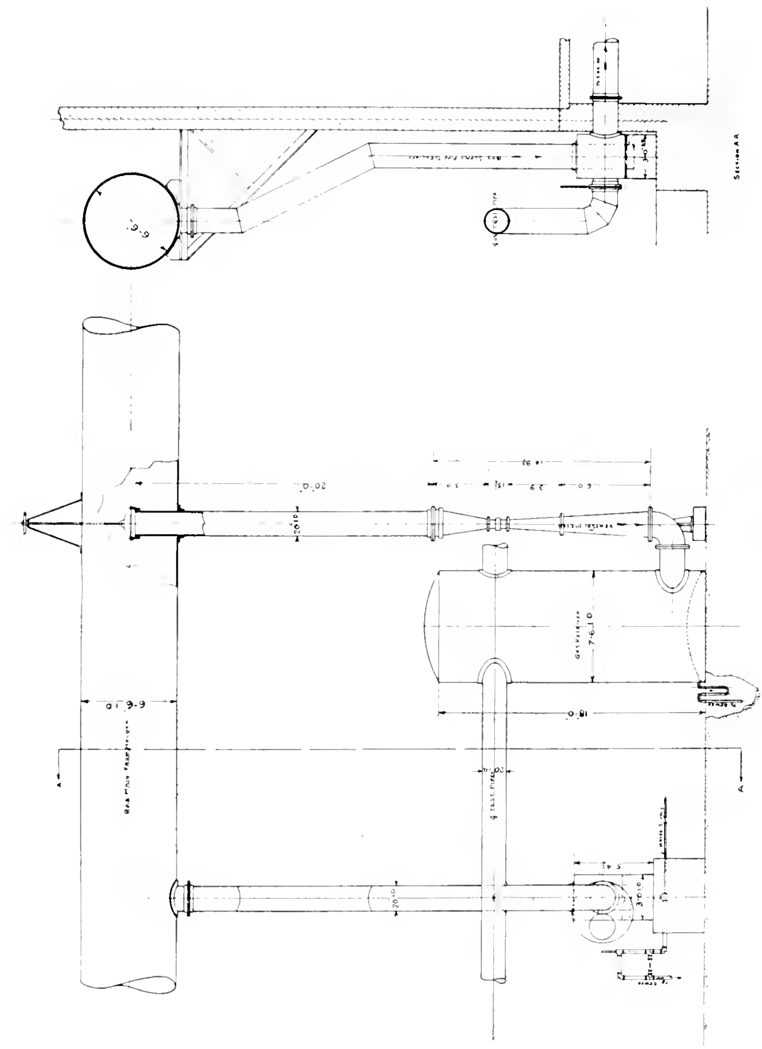


FIG. 23*a* GENERAL ARRANGEMENT OF TEST PIPING

58 The question is often asked, what can be the advantage of keeping exact records if the recorded results vary comparatively little during the year's operation, and whether the game is worth the candle, assuming that the expenditure is far in excess of the benefit derived. The questioner overlooks, however, that only by keeping such records can it be determined whether the conditions really are generally uniform; and that this uniformity is in many instances due to the careful watching and recording of the phenomena involved. Besides it was found, in over two years' experience at the plant under discussion, that the expense of "keeping the finger on the pulse" of the gas power plant is so small and so easily absorbed that it is insignificant. The expense connected with the maintenance of a special gas laboratory, for instance, has never as yet noticeably increased the cost of pig iron, and the three-hourly readings at the gas cleaning plant are being taken, without additional expense, by the operators themselves, who are assisted and checked in their work by recording instruments installed wherever expedient. It has been found, too, that the installation is being given much more care by the operators, since they are compelled to go over the whole plant on regular beats, in order to take the various readings. The general appearance of the gas cleaning plant shows unmistakably the influence of this continuous inspection. It is only natural that the operators should themselves become interested in their readings and compare the results from day to day. They soon make changes and improvements in the equipment, of their own accord, and will operate the plant at a much higher standard of efficiency.

59 Fig. 6 and Fig. 24 show two of the standard record forms, which are self-explanatory. The data collected on the various report sheets are tabulated and plotted on charts in the engineering department so as to show the daily, monthly and yearly averages. These records are very valuable from an operating point of view. The economy of a gas-purifying plant, for instance, is dependent on a number of elements, among which the plant efficiency is not of least importance. It involves the question of total cost per unit of gas, of electric light and power consumed in the plant, of operating labor, labor and material used in repairs, and lubricants in relation to the degree of cleanliness and the amount of moisture obtained by this total expenditure in the same gas unit. The majority of these elements can be controlled when the variations to which they are subjected are known, by voluntary or involuntary changes, but this knowledge can be acquired only through close and continuous observation.

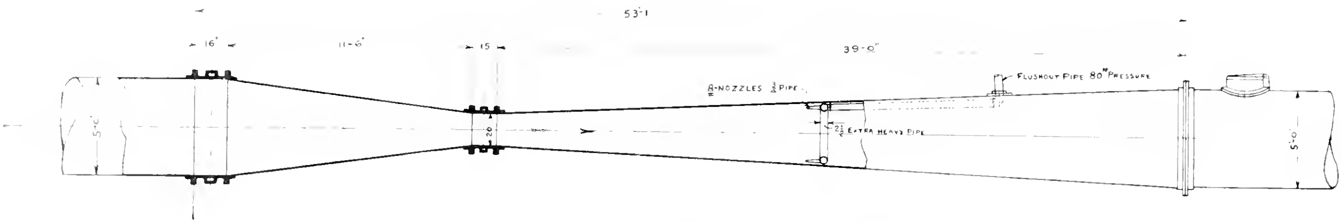


FIG. 23b TEST PIPING—60-IN. VENTURI METER

PRESSURES AND TEMPERATURES-DAILY REPORT FOR 24 HOURS ENDING 6 A.M. Thursday, October 7th, 1909.

TIME		GAS TEMPERATURES (F) PRESSURES ("OF WATER)														WATER TEMPERATURE							READING OF AMMETER ON THEISEN WASHER MOTORS — AMPERES PER TERMINAL								WATER CONSUMPTION GAL. / MIN.		No. of Electric Engines in Operation	No. of Blowing Engines in Operation
		Entering Gas Cleaning Plant		After Wet Scrubbers				Before Theisen Washers		After Theisen Washers		A. C. Sta. Gas Holder		B. Engine Gas Holder		Pump Suction	Wet Scrubber Waste				Waste Theisen Washers	Air Temperature												
				1	2	3	4					In	Out	In	Out		1	2	3	4			1	2	3	4	5	6	7	8	Scrub.	Th.		
		T	P	T	T	T	T	T	P	T	P	T	T	T	T																			
DAY TURN	8 A.M.	218	17.0	—	—	77	64	68	16	68	22	67	65	—	—	67	—	—	96	69	70	66	—	—	155	155	—	—	—	—	1400	300	3	—
	11	195	13.5	—	—	83	71	76	16	76	21	75	71	—	—	69	—	—	98	71	72	76	—	—	155	155	—	—	—	—	1400	300	3	—
	2 P.M.	204	14.0	—	—	82	75	77	13	77	19	79	77	—	—	71	—	—	101	76	77	72	—	—	155	155	—	—	—	—	1400	300	3	—
	5	208	15.5	—	—	82	72	74	15	74	21	71	72	—	—	71	—	—	101	76	77	70	—	—	155	155	—	—	—	—	1400	300	4	—
NIGHT TURN	8	184	16.0	—	—	76	68	72	15	73	18	73	68	—	—	70	—	—	100	72	73	69	—	—	155	155	—	—	—	—	1400	300	4	—
	11	202	14.0	—	—	78	70	73	13	74	16	72	68	—	—	72	—	—	102	73	74	68	150	—	—	155	—	—	—	—	1400	300	4	—
	2 A.M.	200	13.0	—	—	76	67	71	12	71	15	68	65	—	—	70	—	—	98	71	72	67	150	—	—	156	—	—	—	—	1400	300	4	—
	5	180	14.0	—	—	72	66	70	13	68	16	67	64	—	—	70	—	—	98	71	72	65	150	—	—	155	—	—	—	—	1400	300	4	—
AVERAGES		199	15.0	—	—	78	69	73	14	73	18	72	69	—	—	71	—	—	100	72	73	69	150	—	155	155	—	—	—	—	1400	300	—	—

SUPPLIES RECEIVED

OBSERVATIONS

Started Bilus pump at 8:00 A.M. shutting down centrifugal pump.
Repacked centrifugal pump and started again, shutting down Bilus pump at 11:00 A.M.
Started Theisen washer No.1 at 3.00 P.M. shutting down washer No.3 on account of bricklayers working around No.3 motor.

Martin Mullin — Day Operator
Mike Smolinski — Night Operator

FIG. 24 DAILY REPORT FORM FOR GAS-CLEANING PLANT

60 Suppose, for example, the dust determinations of a certain day, or of several consecutive days, show a much higher amount of impurities in the engine gas than usual. Steps to remedy this condition may be taken immediately. As a rule an increased amount of water in the preliminary washing plant, or on the Theisen washers, will have the desired effect; or an additional washer can be started, thereby decreasing the load on each unit and giving the gas an additional scrubbing. Without the daily record this increase in dust might not be noticed until trouble arose in the engines; or a clogging of the wet scrubbers or of the gas flues might not be noticed until the effect of a restricted gas passage was shown in the reduced output of the power plant.

61 For example, on consulting the daily records in September and October 1908, it was noticed that the gas pressure between the two wet scrubbers was considerably lower than that in the collecting flue, a state of affairs particularly annoying at that time as another period of insufficient gas supply was on hand. It was first thought that the hurdles in wet scrubber No. 1 were clogged by dust bridging over between slats. Simultaneous readings of the pressure gages on either side showed a difference of $1\frac{1}{4}$ in. to $2\frac{1}{8}$ in. After flushing the scrubber for 30 minutes by opening wide all the top sprinklers and side flush-outs, which are situated half way between top and bottom of the scrubber, and using 1,800 gal. of water per minute, this difference did not disappear, indicating beyond a doubt that no obstruction had occurred in the scrubber. It was finally found that the scrubber inlet pipe was nearly filled with mud at the point where it turns at a slight angle into the wet scrubber shell and a heavy stream of water soon removed the obstruction.

62 In March 1909 the amount of flue dust in the dry cleaned gas increased rather suddenly from 0.56 grains per cu. ft. on March 3 to 1.53 grains per cu. ft. on March 5. The amount of water on wet scrubber No. 2 was increased from 400 to 500 gal., and decreased from 400 to 350 gal. per min. on the Theisen washers. The effect was a material improvement in the wet scrubber efficiency, while the amount of dust in the fine gas was hardly affected. This is illustrated in Fig. 25, showing the daily averages of the dust contents in the gas, etc. In this manner the total amount of water for wet scrubbers and Theisen washers as well as the relative quantities for scrubbers No. 1 and No. 2, were changed frequently during the year to conform with the demands indicated by variations in the recorded results. The methods and instruments used to obtain these records are given in Appendix No. 3.

RECORDS AND RESULTS OF OPERATION OF THE DRY-CLEANING PLANT

63 Before the existence of the dry cleaning system at the blast furnaces the two dry dust catchers in the preliminary gas-cleaning plant proved very satisfactory in operation and efficiency, and the effect of unlined gas flues and dust catchers on the reduction in temperature of the gas was greater than had been anticipated. The temperature at which the gas leaves the furnace top averages about 400 deg. fahr. with the furnaces in normal operating condition. This temperature may, however, reach 700 and 800 deg. when abnormal conditions of operation are caused by high coke consumption, irregular working, etc., and furthermore when special grades of iron, such as ferrosilicon or spiegeleisen are produced. When formerly all furnaces discharged their gas directly into the brick-lined overhead flue the temperature of the gas at the entrance of the gas-cleaning plant was considerably higher. Thus in 1908 the average temperature at the main water seal, according to Bristol pyrometer records, was as follows in degrees fahrenheit:

March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.
650	500	483	531	426	410	303	312	299	329	425

The drop in temperature of the gas, due to radiation of heat through the walls of unlined piping and dry dust catchers, was quite pronounced. See Appendix 4, Table 1. In round numbers about 50 per cent of the sensible heat carried by the gas into the dry-cleaning plant was removed by radiation.

64 An attempt was made to determine the number of B.t.u. radiated per hour per square foot of radiating surface of the dry dust catchers to obtain a basis for future calculations. For five different days the B.t.u. loss per square foot of radiating surface per degree difference in temperature per hour was 1.29; 0.99; 1.105; 1.11; 1.33; with an average for all observations of 1.165.

65 After the dry dust catcher system at the blast furnaces was put in operation conditions changed considerably, as the gas passing through the voluminous unlined dry dust catchers and the overhead gas main, the brick lining of which had been removed in April 1909, lost so much heat by radiation that it entered the gas-cleaning plant at a much lower temperature than before. This temperature is very uniform at present, averaging about 300 deg. fahr. The heat-radiating effect of the dry-cleaning plant, however, is maintained, reducing the average temperature of the gas before it enters the wet-cleaning

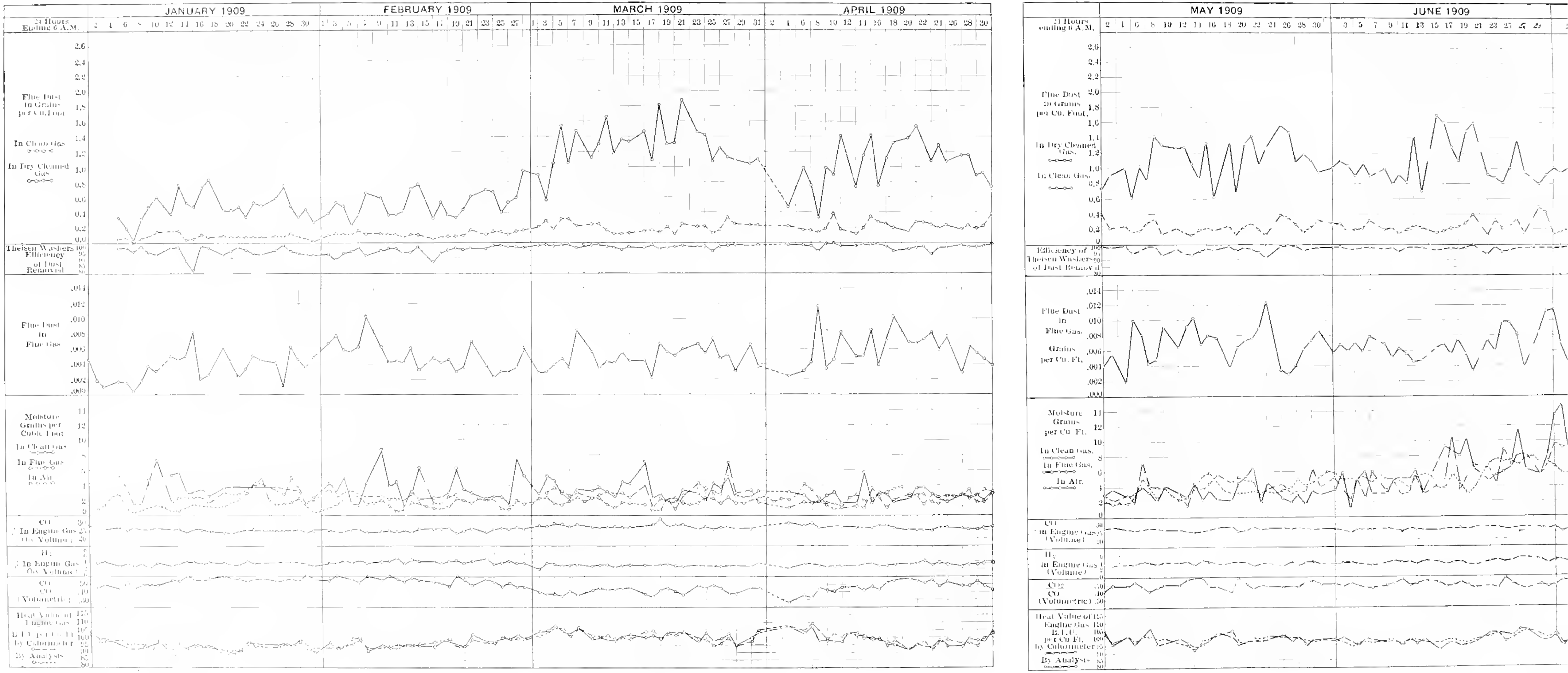
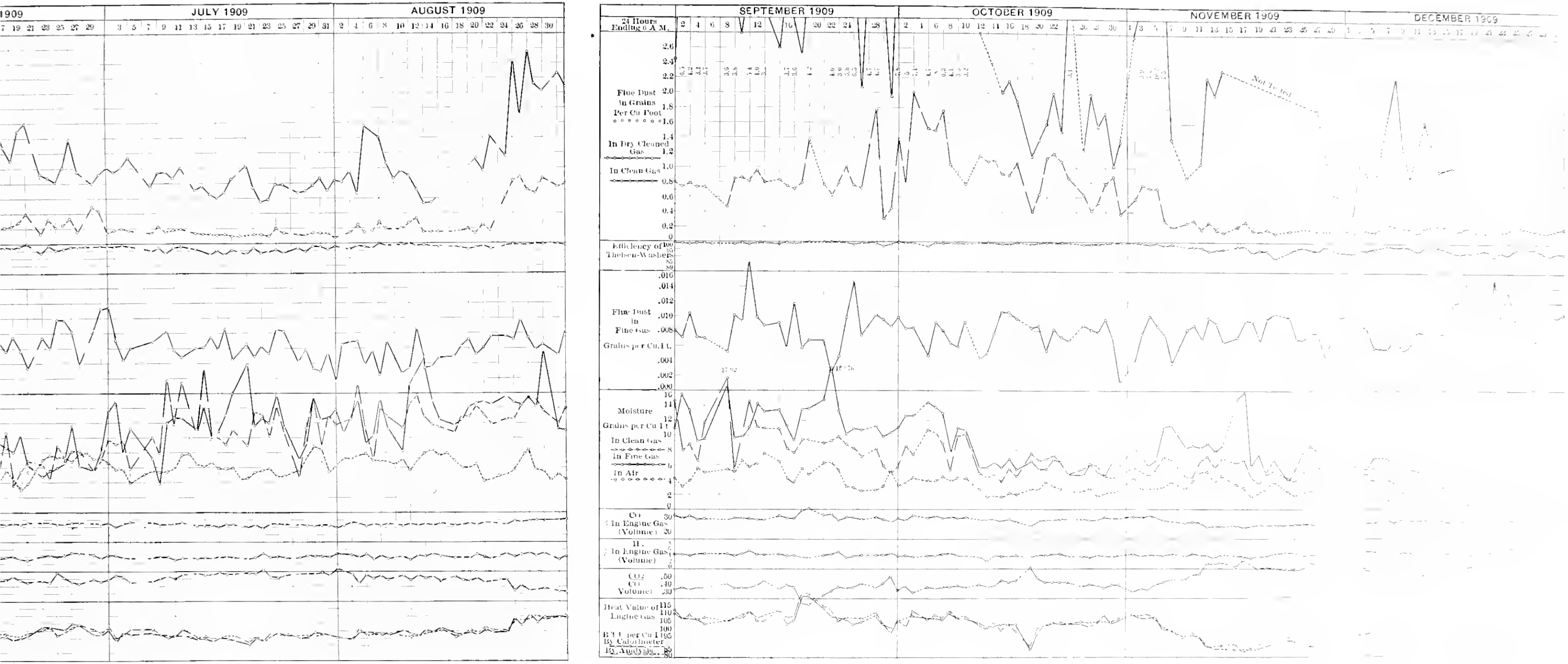


Fig. 25 Condition and Composition o



on and Composition of Gas Daily (Averages)

plant about 56 per cent as shown in Fig. 26, which gives the average monthly figures for 1909. Since the cooling effect takes place without the use of water, it is obtained entirely without cost.

66 This cooling of the gas to a temperature considerably below 212 deg. in 1909 caused heavy condensation of moisture in the pipes and

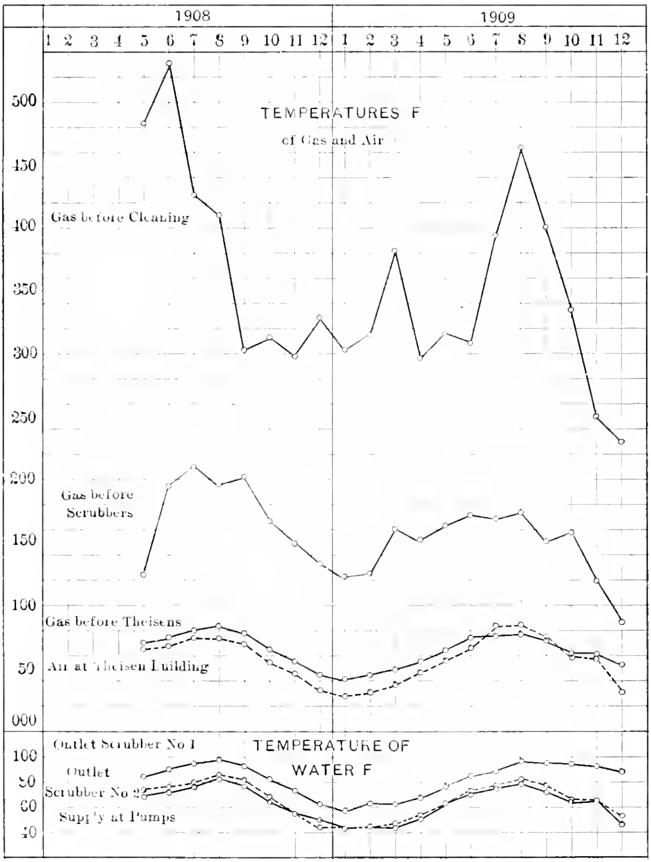


FIG. 26 TEMPERATURES OF GAS, WATER AND AIR (MONTHLY AVERAGES)

dry dust catchers. This proved to be of considerable value in the process of gas cleaning, since the finer particles of dust were weighed down by microscopical globules of water and thus more easily separated from the gas. The dust removed in the dry cleaning plant appeared mostly in the form of mud, which accumulated at all points of

change in direction of the gas flow, and especially in the dry dust catchers where the velocity was very small. The difficulties encountered in trying to remove this mud during the operation of the plant formed one of the reasons for abandoning the dry dust catchers at the gas-cleaning plant. As outlined in Appendix No. 3, several attempts to obtain reliable data concerning the dust-removing efficiency of the dry-cleaning plant proved futile, but an idea can be gathered from the fact that on an average a carload of dry dust weighing about twenty-five tons was removed every other week, while a large quantity was blown away by the wind.

67 The condition in which the gas was delivered to the next stage of cleaning is shown in charts (Figs. 25, 27 and 28) and in Appendix 4, Table 2, wherein the monthly averages as well as the daily variations of the dust contents in the dry cleaned gas are given. These curves and particularly Fig. 28, which gives the daily amount of flue dust in dry cleaned and clean gas for the period from August to December 1909, drawn to a larger scale, indicate quite violent fluctuations which are due to different operating conditions of the blast furnaces.

68 Heavy slipping will naturally increase the dust contents in the raw gas beyond measure. It has an effect very similar to an explosion, as the sudden upheaval of the stock in the furnaces causes a momentary rise in the gas pressure, illustrated on pressure chart Fig. 1. The velocity of travel of the gas through the pipe lines after a slip can easily be observed in the rapidity with which clouds of flue dust belch forth from boiler stacks, nearly 1,000 ft. from the source of disturbance, only a very few seconds after the slipping. Besides the momentary increase in the quantity of dust caused by slipping the furnaces, considerable amounts are added from the deposits of flue dust in pipe lines, dust legs and dry dust catchers, accumulated for hours and days, and disturbed by the sudden high velocity of the gas.

69 The nature of the furnace product has a great deal of influence on the quantity of flue dust produced. While Bessemer and basic furnaces produce about equal amounts in the plant under discussion, ferrosilicon and spiegel furnaces make very much more, which moreover is very fine and cannot easily be removed from the gas—especially not by dry cleaning alone. Thus for instance a sudden increase of 270 per cent in the dust contents in the dry cleaned gas occurred in March 1909, due to the following cause: For several months previous the raw material charged into the furnaces had been considerably "watered" to reduce top temperatures and flue dust losses. On

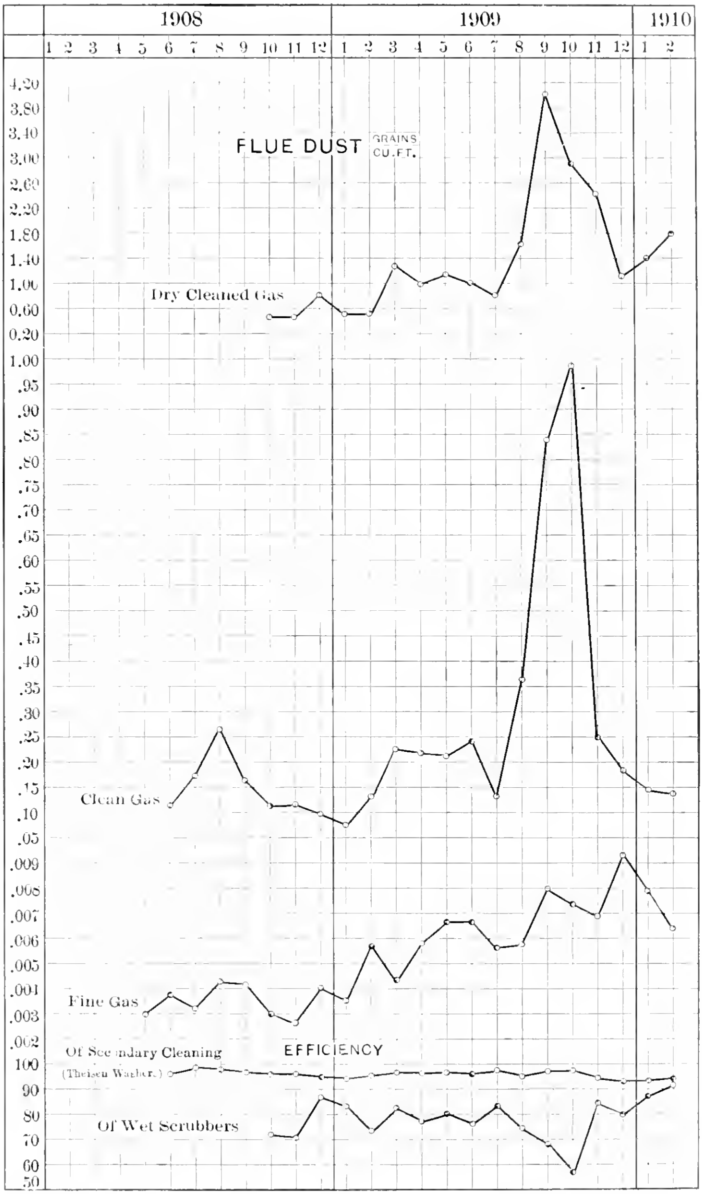


FIG. 27 FLUE DUST IN GAS AND EFFICIENCIES OF CLEANING PLANT (MONTHLY AVERAGES)

February 28, 1909, the watering of the stock was suddenly discontinued. The result was an increase of nearly 100 per cent in the dust contents in the dry cleaned gas, as shown in Fig. 25. It begins with the day ending March 4 and shows great fluctuation, while after March 24 a sudden decrease occurs and the amount of dust for the rest of the month shows considerably more uniformity.

70 The reduction was due to the fact that on March 24 the watering of the stock was resumed in a moderate way. The average amount of flue dust in the dry cleaned gas in February was 0.4787 grains, against 1.2951 grains per cu. ft. in March, the corresponding increase of dust in clean gas being from 0.1224 grains in February to 0.2238 grains per cu. ft. in March, or about 200 per cent. The quantities of gas cleaned per minute were almost exactly the same, namely 14,765 cu. ft. in February and 14,717 cu. ft. in March, so that the records are directly comparable. It cannot be estimated even, how much dust the raw gas contained during March, but when the dry dust catchers were opened for examination on April 3 it was found that the mud in the bottom cones had accumulated to the umbrella, while large dust and mud deposits were discovered in the piping even, the latter having lost its self-cleaning qualities due to the nature of the deposits, which in their muddy condition refused to slide down into the dust legs.

PERFORMANCE OF WET-SCRUBBING PLANT—COOLING AND CONDENSING EFFECT

71 The preliminary wet-scrubbing plant was particularly successful and efficient, and the operation of the wet scrubbers has been continuous ever since starting in November 1907. Several examinations of the wet scrubbers took place, at times when the gas power station was shut down entirely, and it was invariably found that both were in perfect condition. Aside from a thin coating of slimy flue dust, which seems to have penetrated into the pores of the wood, there was no sign of any deposit on or around the hurdles. Since oxygen is practically entirely absent, rotting of the woodwork is impossible. From observations of the condition of the wet scrubbers the conclusions may be drawn that it is unnecessary to be particular in selecting the quality of lumber for manufacturing the slats and that dressing it all over could possibly be dispensed with. The distance between the slats could be made very much smaller than in the two original wet scrubbers, and a spacing of about three inches was adopted for

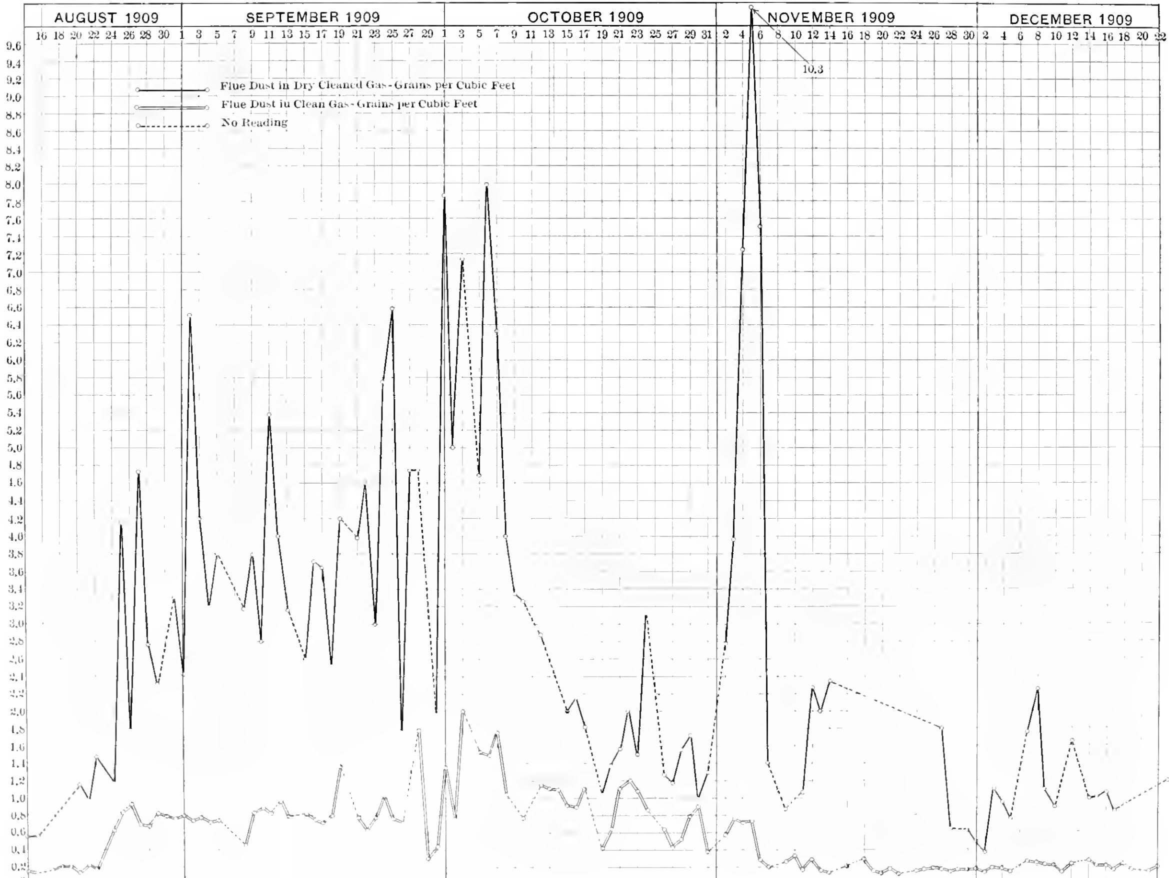


FIG. 28 FLUE DUST IN DRY CLEANED AND CLEAN GAS

the two new ones. No difficulties of any description were encountered in the operation of these scrubbers, and the overflow arrangement from the water sealed basins, shown in Fig. 11*b*, as well as the disposal of the dirty washing water never caused any trouble.

72 In Fig. 26 and in Appendix 4 (Table 3) are shown the effects of wet cleaning upon the temperature of the gas and the corresponding fresh and waste water temperatures. A comparison of the curves shows that the gas was cooled practically to water temperature, and records show that this cooling action is nearly limited to the first wet scrubber, as the temperature of the gas between the wet scrubbers was only a few degrees higher than the clean gas temperature. The average temperature of the clean gas for the first half year was 54.7 deg., while the temperature of water supply was 53.3 deg. for the same period. For the second half of 1909 these temperatures were 67.4 and 66.7 deg. respectively. The yearly average temperature of the clean gas was 61.1 deg., while the yearly average temperature of the water supply was 60.0 deg. The temperature of the waste water from scrubber No. 1 was on an average 20 deg. higher than the temperature of the fresh water, while the water from wet scrubber No. 2 did not exceed the average water supply temperature more than 1.7 deg. fahr. The first wet scrubber naturally removed the bulk of the dust, as was indicated by the muddy, black appearance of the waste water, but a good share of the cleaning was done by the second scrubber, judging by the reddish-brown color of the water discharged.

73 The cleansing efficiency of the wet scrubbers, that is, the ratio of the amount of dust removed by the scrubbers to the total amount which they receive is given in Figs. 25, 27 and 28 and in Appendix 4, Table 2, showing the amount of flue dust in clean gas, with its daily and monthly variations. The average efficiency of the wet scrubbers was nearly 80 per cent during the first, and 78.8 per cent during the second half of 1909, while the average yearly efficiency reached 79.3 per cent. The drop in the second half, and particularly in September and October, is due to the ferrosilicon and spiegeleisen runs on blast furnace No. 1. If the relatively high amount of dust in the dry-cleaned gas for the same period is considered, as well as the fact that silicious dust is exceedingly difficult to remove, this reduced efficiency is not surprising.

74 Of greatest interest is the effect of wet cleaning on the amount of moisture in the gas. This information is given in Fig. 25 and Fig. 29. While the quantity of water used at the wet scrubbers was considerable, averaging 82.8 gal. per 1000 cu. ft. of gas cleaned, the aver-

age amount of moisture in clean gas was only 6.62 grains per cu. ft. with a maximum of 13.243 grains in August and a minimum of 2.61 grains in April. By comparing these figures with the corresponding average amounts of moisture in atmospheric air, an interesting coincidence will be noted, as the maxima in both cases occurred in August while the minima obtained in April. In Appendix 4 are detailed results of tests made to determine the cooling and condensing effects of the wet scrubbers.

PERFORMANCE OF SECONDARY CLEANING PLANT

75 The Theisen gas washer installation in the secondary cleaning plant was very successful, both in regard to the mechanical operation and the cleaning efficiency of the washers. Theisen washer No. 1, started in 1907, was opened for examination on February 6, 1909,

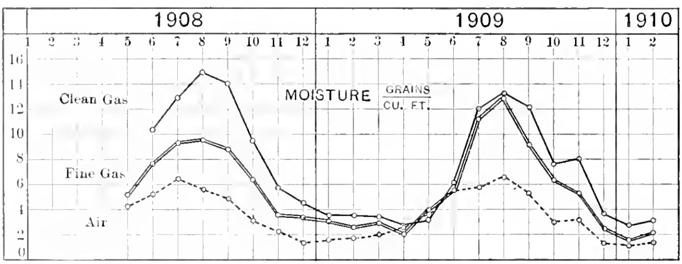


FIG. 29 MOISTURE IN GAS AND AIR (MONTHLY AVERAGES)

after about 7,400 hours of operation. The condition of this washer was as follows: The drum was almost perfectly clean, the longitudinal vanes showing a coating of soft mud about $\frac{1}{2}$ in. in thickness and 10 in. in length on the back side near the gas inlet. The total amount of mud and dust on the vanes when dried filled a $3\frac{1}{2}$-gal. water pail twice, and, except to repaint the drum, the washer needed no attention. The paint was worn off the front of the vanes only, especially on the outer edges. The wear of the water on the longitudinal vanes, due to its velocity and its contents of granulated cinders, was quite noticeable at the points were the water happened to impinge. On account of a slight construction defect and the inadvertent use of hard high-carbon steel in their manufacture some of these vanes cracked along their rivet holes and needed replacing. Softer low-carbon steel has since been used and the longitudinal vanes braced, as shown in

Fig. 19, and this trouble has not again occurred. The wear in the babbitt-lined bearings allowed the shaft to lower about 1/32 in.

76 The wire netting was absolutely clean, while somewhat corroded in places on the bottom, and the claim that this washer is self-cleaning was fully substantiated by the examination. Theisen washer No. 2 was opened in March 1910 for its second examination after nearly 9,300 operating hours, and its condition was found to be equally satisfactory. The accumulations of mud were very slight as shown in

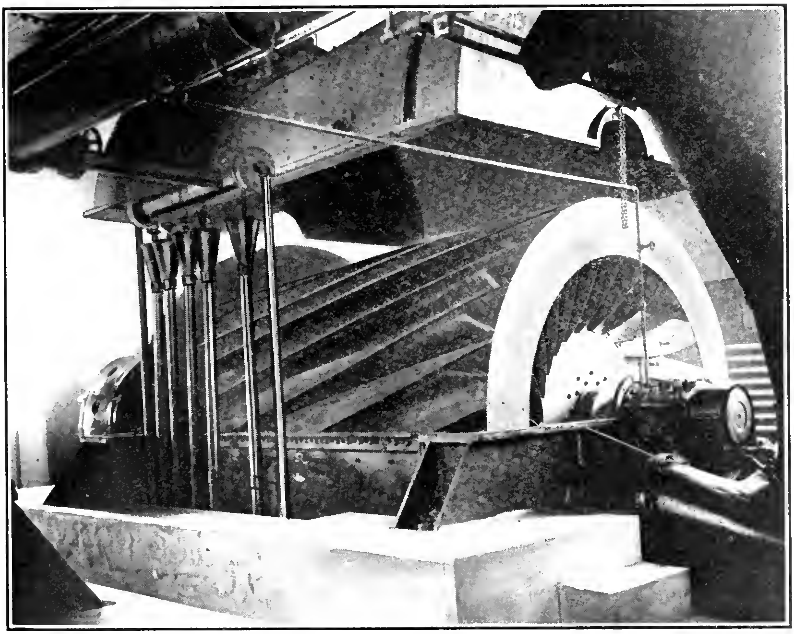


FIG. 30 THEISEN WASHER DURING EXAMINATION

photographs, Fig. 30 and Fig. 31, which were taken immediately after removing the top half of the casing. The washers can run continuously for months without being shut down, except for occasional cleaning of the motors. All smaller repairs on these washers, as well as on the whole gas-cleaning plant, are made by the operators, and the expenditure for lubricants and other supplies is amazingy small.

77 The chart in Fig. 2 shows that the average gas pressure after the Theisen washers was only slightly in excess of the aver-

age raw gas pressure, the difference being about 3 in. of water column. The advantage of this slight pressure difference is obvious, in contrast with the considerably higher pressure given by so-called hydraulic fans. Superfluous pressure for the transmission of the gas to the point of consumption, must be paid for in excess power. The gas temperature at the Theisen washer inlet was practically water temperature, while the temperature of the gas delivered by the Theisen washers was found to be on an average 2 deg. to 3 deg. higher, a difference

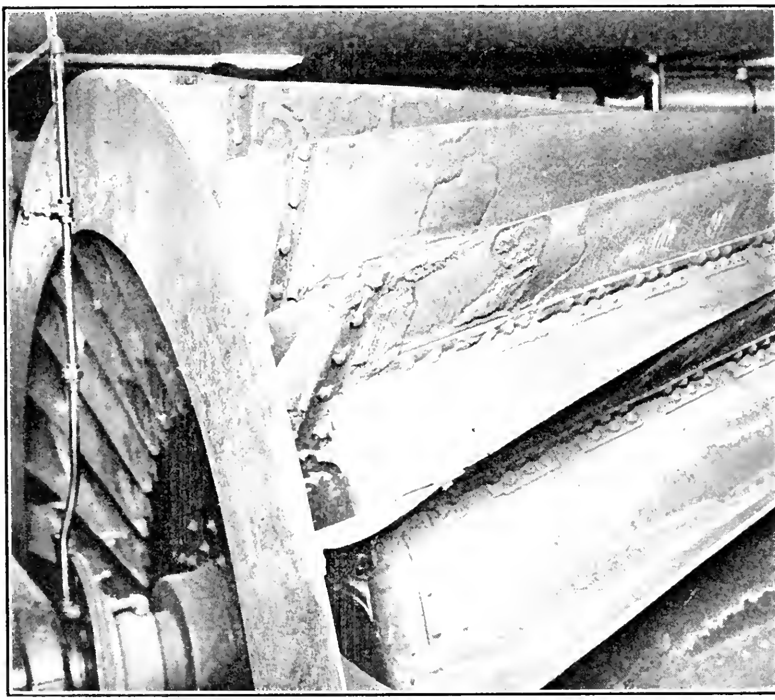


FIG. 31 THEISEN WASHER—DETAIL OF DUST DEPOSIT

explained by the fact that the mechanical work consumed by the Theisen washers must be transformed into heat, which in portion is imparted to the gas. On its way to and in the gas holder this heat is again radiated, so that the gas temperature at the engines practically equals the temperature of water supply, and only a little difference can be observed between the atmospheric temperature and the temperature of the fine gas (See Fig. 26).

78 The performance of the Theisen washer as a gas cleaner, considering the variety of conditions of furnace operation, was beyond reproach. By referring to the daily and monthly averages, given in Table 4 of Appendix 4 and plotted in the charts in Fig. 25 and Fig. 27, it will be noted that the efficiency of the secondary cleaning plant, that is, the ratio of the amount of dust removed by refining to the total amount contained in the clean gas leaving the preliminary washing plant, averaged 98.1 per cent. While this figure in itself is remarkable, it is of much more importance that this efficiency, as shown by the close coincidence of the monthly average figures, was exceedingly uniform, varying from a maximum of 99.1 per cent in October, to a minimum of 95 per cent in December 1909. The average efficiency for the first half-year was 97 per cent, while the corresponding figure for the second half reached 98.7 per cent. The great variations to which the amount of flue dust in dry cleaned gas was subjected during the year, especially however in March and April and during the period from the latter part of August until the middle of December, did not particularly affect the efficiency of the secondary cleaning plant, since in September and October, when the amount of flue dust in dry cleaned gas averaged 3 to 4 grains per cu. ft., the efficiency of the secondary washing plant shows a very marked uniformity—the average from August 25 until November 5 being 98.87 per cent—while the efficiency of the wet scrubbing plant gradually decreased from 83 per cent in July to 75 per cent in August, 69 per cent in September, and 57 per cent in October. The amount of flue dust in fine gas during these months was, of course, higher than in any previous period, but the efficiency of refining was nearly a constant maximum, irrespective of the dust conditions of raw and clean gas and of the quality of the flue dust.

79 During September and October, when furnace No. 1 made its ferrosilicon run, the color of the waste water from wet scrubbers and Theisen washers was very milky, and the dust so high in quantity, and so peculiar in quality, that considerable accumulations occurred in the clean gas main and at the inlet gate valves of the Theisen washer. The silicious flue dust seemed to set like cement, and lumps of considerable size and of great hardness had to be removed with a bar, from the inlet gate valves of the Theisen washer. Nevertheless the efficiency of the secondary washing plant during these two months was higher than during any other period.

80 In the previous paragraph the term "efficiency of the secondary cleaning plant" was used deliberately in order to indicate that in

this remarkable showing gas mains and gas holder participated. The clean and fine gas flues, connecting wet scrubbers, Theisen washers and power station gas holder, have a combined length of approximately 1000 ft., and a diameter of 5 ft. 6 in. and 5 ft. respectively. The total quantity of gas passing these mains per minute averaged 16,900 cu. ft., with a maximum of 20,300 cu. ft. in October, and a minimum of 13,600 cu. ft. in January. The velocity of the gas while traveling through these pipes did not exceed therefore 14 ft. per sec. in the clean gas main, and 17 ft. per sec. in the fine gas main. At this low velocity some impurities will undoubtedly drop out in the clean gas main, with the finely divided water which is carried along by the gas. The fine gas main, however, was always found practically clean; and while an examination of the gas holder tank has not been made, it is not believed that any great quantities of flue dust would be found in the bottom of the tank, as the dust in the fine gas is so impalpable that the fine gas burns with absolutely clear blue flame. However, in order not to credit the Theisen washers alone with removing 98 per cent of the dust from the clean gas, the efficiency is stated as embracing the secondary washing plant as a whole, or the combination of gas pipes, Theisen washers, water separators and gas holder.

81 That the Theisen washers must be credited with the bulk of the work is proven by the test summarized in Table 5 of Appendix 4. From the results given it will be seen that the efficiency of the clean gas main averaged 16.5 per cent while the fine gas main and the gas holder removed only 6 per cent of the dust delivered by the Theisen washers, or 0.23 per cent of the dust in the clean gas, proving that but little cleaning is done by gravity and reduced velocity. The Theisen washers had nearly 95.5 per cent absolute efficiency during the week when the tests were made, while their relative efficiency, based on the amount of dust in clean gas, was 79.64 per cent. It is safe to assume that similar conditions prevailed during the year 1909 and that the same relative proportions hold true at any time. The inconsistency in some of the results obtained after the Theisen washers and after the gas holder, which would indicate the impossible condition that the gas picked up a certain amount of dust on its way from washers to holder, is due to the small quantities on the shell of the Brady filter, which have to be dealt with in fine gas and cause errors in observations.

82 Since starting the gas power plant in 1907 the absolute amount of dust in the fine gas naturally continued to increase gradually, corresponding to a similar increase in the amount of gas cleaned per

minute, shown in Fig. 32. At the beginning of operations the gas engines received gas of a degree of cleanliness excessive for practical purposes. Thus the average dust contents in the fine gas in the second half of 1908 was only 0.0036 grains per cu. ft., or 0.0077 grams per cubic meter, which is much less than the average usually guaranteed. An excessive purification of blast furnace gas, even for engine purposes, is unwarranted, because the atmosphere in a steel plant is usually very dirty, and it seems quite out of place to purify the gas to a higher degree of cleanliness than the combustion air, unless the latter is to be subjected to a similar cleaning process. Tests made in July 1909 to determine the quantity of impurities contained in the air near the air intake of the gas engines showed the amount to be between 0.0005 and 0.0052 grains per cu. ft. with an average of determination (given in

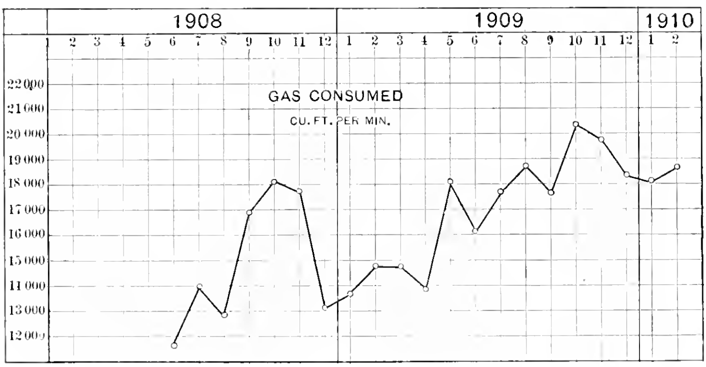


Fig. 32 Gas Consumed, Cu. Ft. Per Min. (Monthly Averages)

Table 6, Appendix 4) of 0.00346 grains per cu. ft. The amount of dirt in the air is therefore by no means a negligible quantity. The detrimental character of these impurities is also apt to be under-estimated. In Appendix 4, Table 7 is a comparison of the chemical analyses of samples of the deposit on the gas and air dampers in one of the gas engines, taken in February 1909. It is to be noted that the gas never comes in contact with the air dampers, so that the samples fairly represent the accumulation of dirt deposited by the combustion air.

83 A comparison of the four analyses shows the surprising fact that the amount of iron in the dust sample taken from the air dampers is about twice as great as in the dust deposited on the gas dampers. If this is true—and there is no room for doubt, as the samples represent the accumulations of more than one year, the dampers never having

been cleaned—it follows that appreciable quantities of iron, sand and coke enter the engines with the combustion air.

QUALITY OF FLUE DUST

84 The chemical composition of the flue dust removed from the gas at various stages of the cleaning process was made the subject of analysis in March 1908. Samples were taken at the following points: dry deposit from the main water seal and collecting flue after dry dust catchers, suspended matter secured by evaporation of samples of the waste water from wet scrubbers No. 1 and No. 2 and the Theisen washers. The results of this test are shown in Table 8, Appendix 4, all analyses giving metallic iron and manganese as Fe and Mn, while the constituents exist in the form of oxides. Fixed carbon is mostly coke, and the volatile is the CO_2 from limestone. This table shows that the relative amounts of silica, alumina, lime, etc., increase gradually, more and more of the heavy impurities such as Fe dropping out the further the cleaning process progresses.

85 A similar test was made in March 1909, with the difference, however, that an attempt was made to determine the quality of the dust remaining in the gas while passing the various stages of gas cleaning. In this case the method of securing samples consisted in connecting Brady filters at the various points and turning the gas on simultaneously at all filters. Irrespective of the size of the gas sample, the cartridges were not removed until sufficient quantities of dust had collected for quantitative and qualitative analyses. It was impossible to obtain a sufficiently large sample for analysis, on the Brady filter installed after the Theisen washers, for while the filter passed the gas very rapidly for a few hours, the flow gradually diminished as the dust in the fine gas closed up the pores of the paper. After a 36-hour run the flow through the filter had stopped completely and the dust collected on the Soxhlet tube appeared as a dull gray coating, which could not be removed. The results of this experiment are given in Table 9, Appendix 4.

86 The relative amount of SiO_2 carried in the gas is practically constant before any wet washing takes place, but the percentage increases in the clean gas, with decreasing relative contents of iron. The wet scrubbers remove the bulk of the iron dust, while the lighter impurities are carried over into the Theisen washers. A sample of the dust deposited in the gas pipe on one of the gas engines immedi-

ately before the gas enters the cylinders at the end of its travel, taken March 15, 1910, was analyzed as follows:

SiO_2	Al_2O_3	Fe	CaO	MgO	Mn	Vol.
36.20	7.53	7.18	12.50	0.90	0.49	34.32

The high percentage of silica, lime and volatile matter, and the very low contents in iron, are noteworthy, and show that silicious dust, lime and coke are carried by the gas much farther than iron, which is removed to the greatest extent in the first stages of cleaning.

87 Due to sulphur in the coke, blast furnace gas contains a certain amount of this impurity in the form of H_2S and SO_2. Its pres-

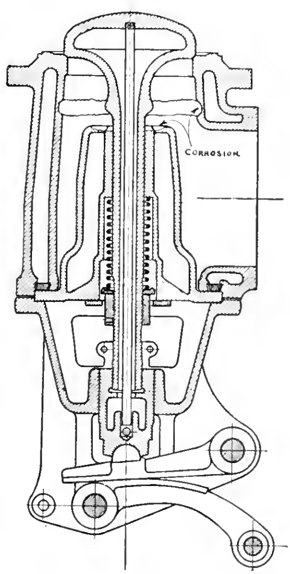


FIG. 33 CORROSION OF VALVE CASING BY SULPHUR IN GAS

ence was discovered after some length of operation of the gas engines. It was found that several of the exhaust valve casings showed very pronounced corrosion, at a place indicated in Fig. 33 and it was concluded that some chemical action had taken place. Two tests made Feb. 2, 1909, showed the presence of 0.0416 and 0.0407 grains per cu. ft. of sulphur in the gas. It was further discovered that the fine flue dust accumulating in thin layers in the gas passages to the engine cylinders, can be lighted and glows with a blue color, unmistakably giving out SO_2 vapors. The corrosion in the exhaust valve chambers was caused by water leaks from the original inner exhaust valve guides,

which cracked as indicated in the illustration. The water coming in contact with the hot exhaust gases formed H_2SO_4, which impinging on the wall of the exhaust valve chamber, had the corrosive effect. The presence of sulphur in blast furnace gas for this reason prohibits the use of sheet-iron exhaust pipes and mufflers, while corrosion has never been observed when cast iron is used. It was attempted, some time ago, to utilize the waste heat from the exhaust of these engines to raise low-pressure steam for use in the heating system of the power house, in wrought-iron pipe coils arranged inside the cast iron mufflers, and while the results were very satisfactory from the standpoint of heat transmission, this heating system was a failure on account of the rapid corrosion to which the heating coils in the mufflers were subjected.

88 The amount of moisture remaining in clean gas, fine gas and air, as well as the variation from day to day and from month to month, are shown in Figs. 25 and 29.

89 While the Theisen gas washers receive the gas at practically water temperature, so that a condensation of water vapors by cooling is improbable, the amount of moisture in the engine gas is nevertheless lower than in the clean gas, and this in spite of the exceedingly intimate contact between gas and washing water in the Theisen washers. The indications are therefore that the Theisen washers remove not only dust, but moisture as well, probably by the action of centrifugal force, which throws gas and water vapors against the circulating water film on the inside of the stationary casing, thereby drying the gas mechanically. Furthermore a great deal of moisture is being deposited in the fine gas main and gas holder. The average moisture in the gas delivered to the engines was 3.39 grains for the first half, and 7.85 grains for the second half of 1909, with a yearly average of 5.62 grains per cu. ft. Comparing these figures with the corresponding values in clean gas and atmospheric air, it will be seen that the average moisture in the engine gas for the year is 60 per cent higher than the average moisture in the atmosphere, which is considered very favorable in view of the high moisture contents in raw gas and the large quantity of water which is brought into such intimate contact with the gas.

90 The effect of the sun beating down on gas mains and gas holder is very noticeable in the summer months, accounting for the high moisture contents in July, August and September. Pipes and holder become quite hot and the finely divided mist in the gas is rapidly evaporated, as indicated by a drip installed near the venturi meter.

Drops or small streams of water are freely discharged in the winter months, while the dripping ceases as soon as the atmospheric temperature exceeds about 78 deg. fahr. The moisture carried with the gas into the engine cylinders has not given cause for trouble at any time.

WATER AND POWER CONSUMPTION OF CLEANING PLANT

91 Fig. 34 shows the average monthly consumption of water since July 1908 in gallons per thousand cubic feet of gas cleaned, as

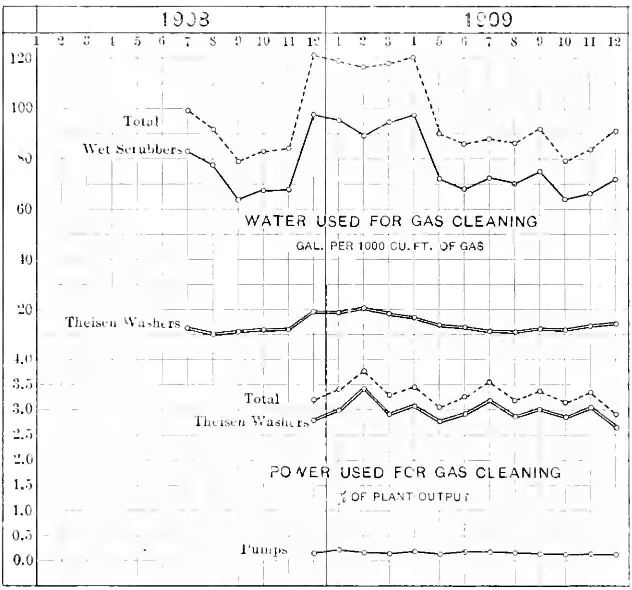


Fig. 34 Water and Power Consumption of Gas Cleaning Plant

established from daily weir measurements. It is to be noted that the water consumption of the wet scrubbers is about four times as high as that of the Theisen washers, for the same quantity of gas cleaned. The latter varied from 26.1 gal. in February to 16.0 gal. in July, with an average of 21.8 gal. for the first and 17.0 gal. for the second half, and 19.4 gal. per 1000 cu. ft. of gas for the whole year. The corresponding figures for the wet scrubbers were a maximum of 103.2 gal. in April, and a minimum of 68.6 gal. in October, with an average of 91.0 gal. for the first half, 74.6 gal. for the second half, and 82.8 gal. per 1000 cu. ft. for the year 1909.

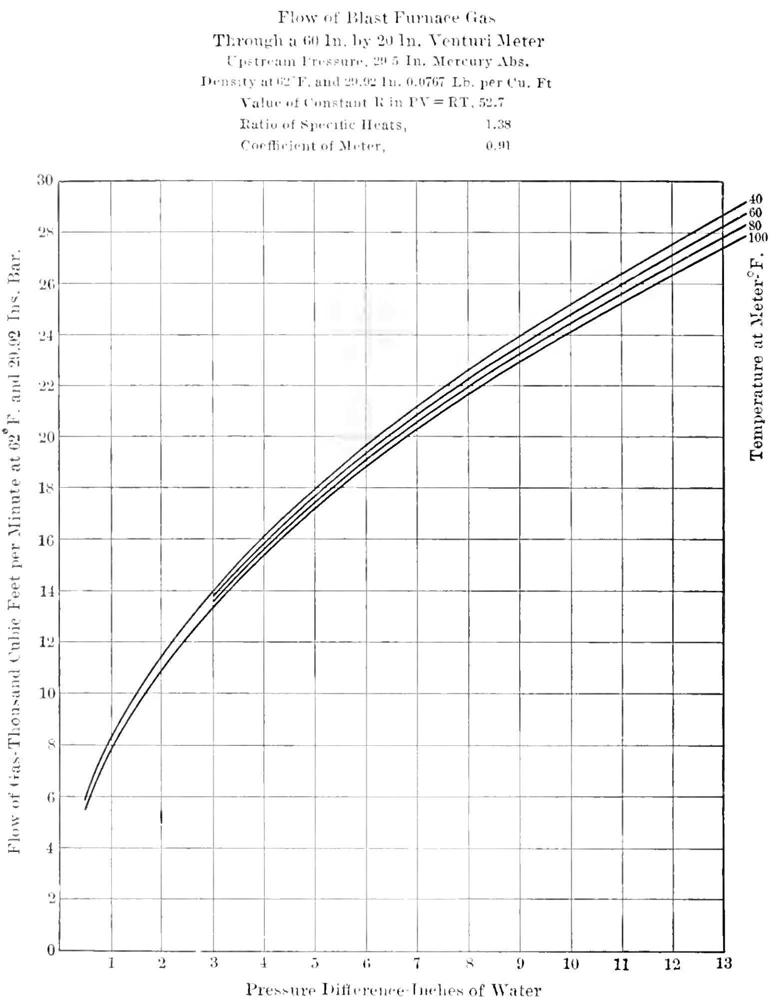


Fig. 35 Venturi Meter Curves Showing Flow of Gas for Different Meter Readings

92 The high water consumption in the first part of the year is due to the smaller quantity of gas cleaned. About the same absolute quantity of water was maintained on the scrubbers. Generally speaking, the quantity of water used in the wet scrubbers could probably be reduced without impairing their efficiency, but it is preferred to use water in excess rather than to run the risk of clogging the sewers, especially since the question of economizing washing water is of no particular importance in a plant located on the lake front.

93 In regard to the amount of power required by the gas cleaning plant, Fig. 34 shows the monthly average power consumption of wet scrubber pumps and Theisen washers, expressed in per cent of the output produced by the gas engines. About 90 per cent of the total power is being used by the Theisen washers, only 10 per cent being

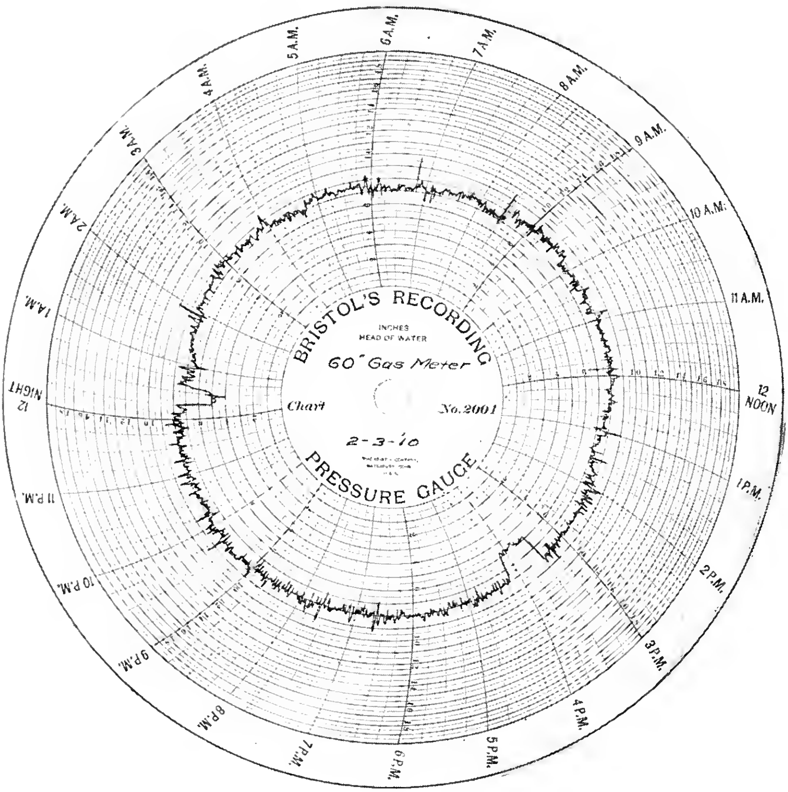


Fig. 36 Bristol Chart of Pressure Differences, 60-in. Venturi Meter

necessary to operate the wet scrubber pumps. The average power consumption of the Theisen washers was 2.977 per cent of the total output of the station, and the respective values for the first and second halves of 1909 were 3.00 per cent and 2.931 per cent, with a maximum of 3.44 per cent in February and a minimum of 2.649 per cent in December.

91 These figures are somewhat higher than are often claimed for similar washers abroad, but an average power consumption for the gas-cleaning plant, of from 3 per cent to 3.5 per cent of the total power output of the gas engines, should not be considered excessive in view

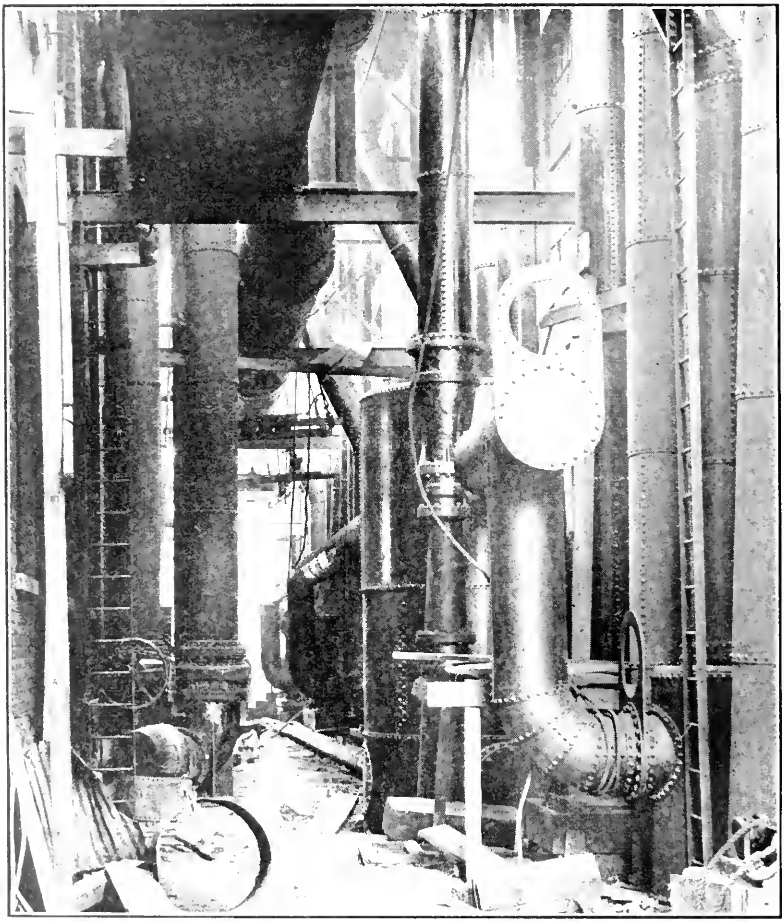


FIG. 37 EXTERIOR VIEW OF TEST PIPING

of the benefit which is being derived from this expenditure. It is worthy of note also that the engine builders who furnished the gas engines for the plant under discussion have never found fault with the physical condition of the gas, while more or less vigorous com-

plaints about "excessive dirt" in the gas are generally advanced as soon as trouble develops in the engines. The necessity of auxiliary machinery is furthermore not characteristic of gas engine installations alone, as boiler-feed pumps, hot-well pumps, dry-air pumps, forced-draft ventilators, mechanical stokers, etc., are indispensable for steam engine plants consuming probably as large a percentage of the power developed.

95 It has been shown in the previous pages that the blast furnace gas was delivered to the gas engines in a highly satisfactory physical condition. The gratifying results of the thorough cleaning and refining of the gas were, that no difficulties which might have been caused by insufficiently cleaned gas were ever experienced in the operation of the gas engines, and these engines never had to be stopped for the specific purpose of cleaning internally the gas valves and gas passages. The amount of dust deposited on internal engine parts was invariably so small that it could be brushed off with the finger, and these engines could undoubtedly operate at full-load capacity a whole year and longer without cleaning the gas inlet passages and cylinders.

96 Blast furnace gas delivered to the power house is charged to operation of the engines at a value based on the price of coal with the cost of cleaning and refining added to the value of the raw gas, which is established on the basis of equivalent heat values. In order to determine the charge made for purified blast furnace gas delivered to the gas power plant, a continuous record is being kept of the quantity of gas blowing to the gas holder, venturi meters being used as measuring instruments. Details of the methods are given in Appendix No. 5. Charts relating to meter measurements are shown in Figs. 35 and 36 of the paper.

THERMAL EFFICIENCY AND OUTPUT OF GAS ENGINES

97 It seemed desirable in connection with the installation of six gas blowing-engines, furnished by three different manufacturers, to provide means for determining the thermal efficiency of each type of engines without interfering with the regular operation of the others. To this end a special venturi meter was installed and connected to a "test" pipe, shown in Figs. 23*a* and 37. By opening the disc valve located inside the overhead gas receiver, which controls the flow of gas through the venturi meter into the large reservoir for equalizing pulsations caused by the intermittent suction strokes, and test piping, and by turning one small spectacle valve while simultaneously

shutting off the direct gas supply from the overhead receiver by filling the water seal, any engine can be operated on measured gas while the others receive gas directly through the branch pipes. Such tests can be commenced at any convenient time, and prolonged and repeated at will. A Bristol differential pressure recorder installed in the blowing engine-room gives continuous records of each test, so that reliable averages can be obtained of the gas consumption under different operating conditions.

98 Fig. 38 shows the monthly averages of the kilowatt output of the power station, of the heat consumption in B.t.u. per kw-hr. and per b.h.p.-hr. based on a generator efficiency of 96.2 per cent at full load, and of the thermal efficiency. The diagram also shows the total operating time of each engine since starting.

99 The thermal efficiency of the plant was very uniform from the middle of 1908 until about May 1909, averaging 23.22 per cent. The drop which began in May and reached a low value in October, was due to certain troubles encountered with gas cylinders and piston rings, etc. These could not be remedied at that time, as on account of the ever-increasing demand of electric power and the lack of a spare unit, it was impossible to shut the gas engines down sufficiently long for a thorough overhauling and for necessary repairs. Doubtless with an additional spare engine the load factor would have been lower than the average for 1909, which reached 72 per cent, but the thermal efficiency would have remained constant—or nearly so—since the necessary repairs, adjustments and changes could have been made on these engines in time, without reduction in the total kilowatt output of the power plant. In spite of this reduced efficiency in the second half of 1909, the average figure obtained for the whole year,—not as the result of one or of several individual tests, but as the fair average of daily observations, proper corrections having been made for the inexact readings caused by dust in the venturi meter in September and October—was 20.8 per cent, with a maximum monthly average of 23.77 per cent in March, and a minimum of 17.8 per cent in October. The highest daily average efficiency in 1909 was 25.7 per cent on March 11.

100 During the year 1909, the engines, while in operation, ran at nearly full-load capacity, the average for the four engines ranging from 93.60 to 99.63 per cent.

101 The values of the total kilowatt output of the gas power plant for each month since regular operation was begun, are plotted in Fig. 39, showing that the maximum output for any month occurred in

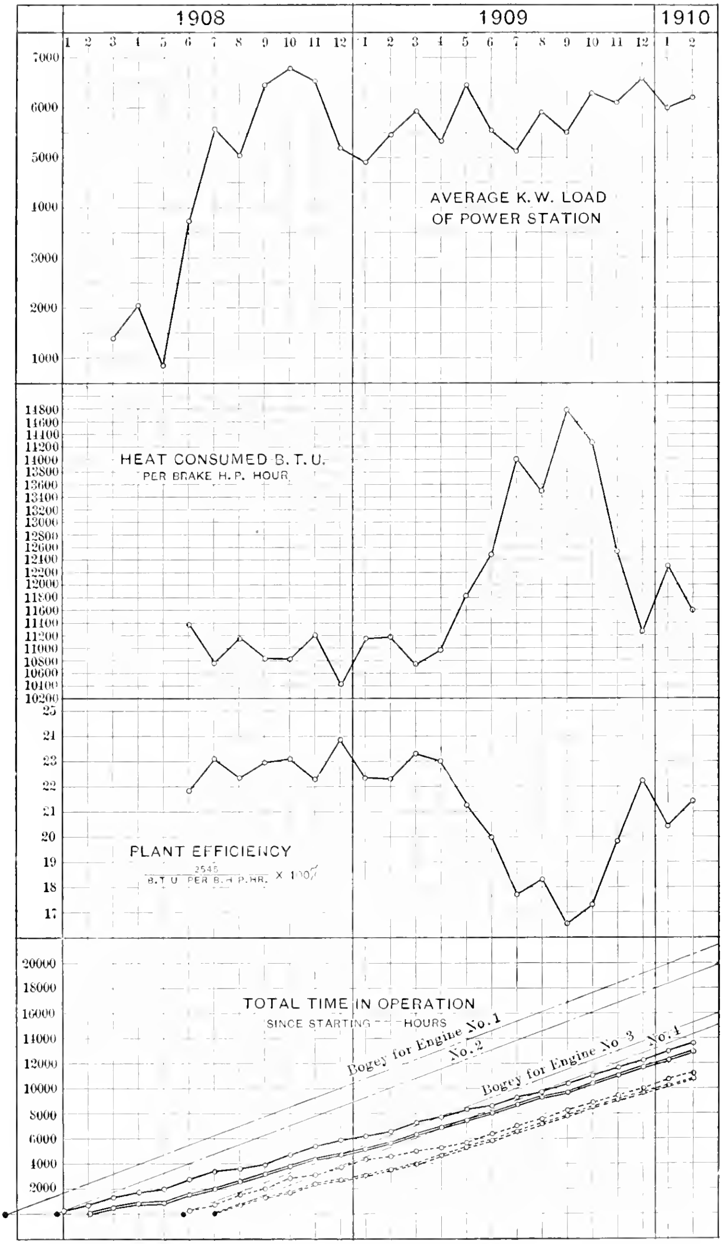


FIG. 38 AVERAGE LOAD, HEAT CONSUMPTION, PLANT EFFICIENCY AND OPERATING TIME (MONTHLY AVERAGES)

October 1908, when 5,000,000 kw-hr. was produced. The output of the gas power plant for the year 1909 was 50,494,100 kw-hr. against 43,953,640 kw-hr. produced by the steam-driven generators. The load factor for 1909 of the gas power plant was 72 per cent, against

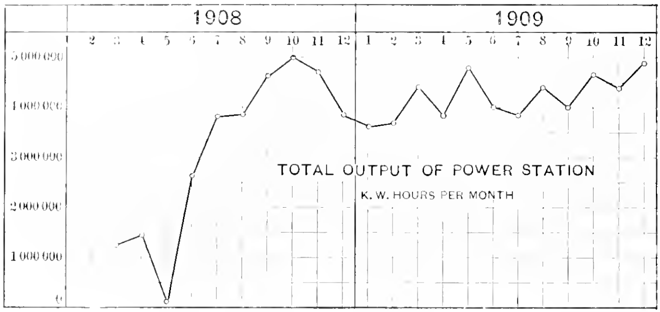


FIG. 39 TOTAL OUTPUT OF GAS POWER PLANTS (MONTHLY AVERAGES)

47 per cent for the steam power stations, which have a rated capacity of 10,900 kw. The total output of electric power generated in 1909 was 94,447,740 kw-hr., 53.5 per cent of which was produced by the gas power plant.

APPENDIX NO. 1

MONTHLY RECORDS OF THE POWER PLANT (8000 KW.)

TABLE 1 MONTHLY RECORD OF KILOWATTS PRODUCED PER HOUR

Month 1909	Kw. per Hr.	Per Cent of Capacity	No. of Furnaces in Blast
January	4920	61.5	3
February	5450	68.0	3
March	5940	74.0	2
April	5330	66.5	2
May	6440	80.5	3
June	5550	69.0	4
Average for first half	5600	70.0	
July	5140	64.0	5
August	5930	74.0	5
September	5500	68.5	6
October	6270	78.0	6
November	6080	76.0	5
December	6600	82.5	5
Average for second half	5920	74.0	
Average for 1909	5760	72.0	

TABLE 2 MONTHLY RECORD OF OPERATING TIME

1909	Plant in Operation		Plant down			
			Due to engines		Due to outside causes	
Month	Hrs.	Per Cent	Hrs.	Per Cent	Hrs.	Per Cent
January	426	57	213	28.5	105	14.5
February	456	68	85	12.5	131	19.5
March	529	71	97	13.0	118	16.0
April	467	65	170	23.5	83	11.5
May	609	82	73	9.5	62	8.5
June	556	77	97	13.5	67	9.5
Average for first half	507	70	123	17.0	94	13.0
July	607	82	103	14.0	36	4.0
August	594	80	131	17.5	19	2.5
September	595	83	107	14.5	18	2.5
October	668	90	52	7.0	24	3.0
November	632	88	65	9.0	23	3.0
December	609	82	52	7.0	83	11.0
Average for second half	617	84	85	11.4	34	4.6
Average for 1909	562	77	104	14.2	64	8.8

TABLE 3 MONTHLY RECORD OF LOSSES DUE TO OUTSIDE CAUSES

Month 1909	Plant down			
	Due to operation		Due to lack of gas	
	Hrs.	Per Cent	Hrs.	Per Cent
January	6	5.5	99	94.5
February	43	33.0	88	67.0
Mareh	36	30.0	82	70.0
April	17	20.0	66	80.0
May	61	98.5	1	1.5
June	59	88.0	8	12.0
Average for first half	37	39.5	57	60.5
July	36	100.0	..	....
August	19	100.0	..	....
September	15	83.5	3	16.5
October	24	100.0	..	....
November	23	100.0	..	....
December	78	94.0	5	6.0
Average for second half	33	97.0	1	3.0
Average for 1909	35	55.0	29	45.0

APPENDIX NO. 2

DATA UPON GAS PRODUCED IN THE BLAST FURNACES

Methods of Calculation of Quantity of Gas Produced

The "nitrogen method" assumes that the nitrogen in the air, amounting to 79.3 per cent by volume, passes through the blast furnace unchanged, so that the same quantity must be found in the exit gas of the furnaces. Since the average gas composition is known, the percentage of nitrogen can be determined by difference. The amount of air blown is based upon the revolutions of the blowing engines corrected for volumetric efficiency of the blowing tubs and for 5 per cent assumed loss of air between tubs and tuyeres. Thus, for instance, in August 1909 blast furnace No. 6 produced on natural blast a daily average of 496.5 tons of Bessemer iron, using 37.5 per cent Pocahontas and 26.5 per cent Connellsvilie coke with an average coke consumption of 2148 lb. per ton of iron. The average gas analysis for the same month was as follows:

CO_2	CO	H	CH_4	N (by difference)
14.23	25.28	4.65	0.23	55.61

B.t.u. per cu. ft. at 62 deg. fahr. = 96.8

B.t.u. per cu. ft. including sensible heat at 500 deg. = 105.3

Temperature of air at blowing engines = 94 deg. fahr.

Cu. ft. of air blown per minute = 40,990

Cu. ft. of air blown per minute at 62 deg. fahr. = 38,610

Average blast pressure = 15.1 lb.

Cu. ft. of air to furnace per minute including 5 per cent loss at 62 deg. fahr. = 36,690

Volume of gas per volume of air at 62 deg. N unchanged = 1,426

Cu. ft. of gas per minute N method = 52,300

According to this calculation No. 6 furnace produced about 153,000 cu. ft. of gas per ton of pig iron made in 24 hours.

2 The nitrogen method, however, is subject to serious errors from the presence of moisture and foreign gases in the air as blown, and from air leakage and inefficiency of tubs. The "carbon method," which is considered more reliable, assumes that the carbon entering the furnace in the form of coke, must reappear in the form of gas, the amount of carbon in the limestone being equal approximately to that in the iron and slag. If A = per cent of carbon in the coke as charged, B = pounds of carbon in 1 cu. ft. of blast furnace gas, the amount of gas produced in cubic feet per minute $= \dfrac{\text{tons of iron per day}}{1440} \times \dfrac{\text{coke rate}}{B} \times A.$

Calculating the amount of gas according to this method, furnace No. 6 liberated 51,310 cu. ft. of gas per min., or 149,000 cu. ft. per ton of product in 24 hours.

TABLE 1 DISTRIBUTION OF GAS FROM BLAST FURNACE NO. 6

August 1909

	Million B.t.u.	Per Cent
Total gas generated	324.1	100
Stoves and leakage	130.0	40
Blowing engines	92.1	28.4
Used at furnace	9.0	2.8
Auxiliaries	4.6	1.4
Total used for blast furnace operation	235.7	72.6
B.t.u. surplus for furnace	88.4	27.4

B.h.p. equivalent of surplus 1470

3 The results of nitrogen and carbon methods, do not, however, always agree as closely as in this instance. The average coke analysis for the month of August, from which the amount of carbon charged into the furnace was determined, was as follows:

	Per cent moisture	Per cent fixed carbon (dry)
Pocahontas	2.64	90.10
Connellsville	1.94	87.38

4 For the distribution of gas it is assumed that 40 per cent goes to the stoves and is lost by leakage. The amount of gas used for the blowing engines is calculated from the boiler horse power, the latter being determined by the quantity and pressure of air blown, the steam rates of engines and the evaporation per boiler horsepower. The B.t.u. equivalent of boiler horsepower for steam distribution in the current month is equal to $\frac{\text{boiler h. p.} \times 33{,}320}{\text{boiler efficiency}}$ and the latter is arbitrarily assumed to be 55 per cent. It is further assumed that 150 boiler h.p. is used in steam at each blast furnace and that all auxiliaries use 5 per cent of the steam going to the blowing engines. The difference is the surplus gas per furnace available for other departments, which is stated in the equivalent of boiler horsepower. Using the former example for an illustration, the total amount of B.t.u. in the gas produced per hour by furnace No. 6 was in August 1909, according to the carbon method, 324.1 million. The distribution was as above in Table 1.

5 The surplus gas was used for operating gas engines in the gas electric station and for raising steam for steam electric power. In this way a B.t.u. balance can be made for all furnaces in each month, as the total kilowatt hours produced in the electric stations and the amount of coal which had to be fired under the boilers are known.

TABLES RELATIVE TO BLAST FURNACE GAS

TABLE 2 GAS PRESSURES

Monthly Averages, Inches of Water

1909	Jan.	Feb.	March	April	May	June	Jan.-June Average
Entering gas cleaning plant..	5.0	5.7	7.3	7.6	7.1	7.6	6.7
After Theisen washers	8.0	8.0	10.1	9.4	9.7	9.8	9.2
Barometer, inches of mercury	29.44	29.24	29.21	29.36	29.31	29.40	29.33

	July	Aug.	Sept.	Oct.	Nov.	Dec.	July-Dec.	Jan.-Dec.
Entering gas cleaning plant	9.1	10.0	12.0	13.4	14.6	12.2	11.9	9.29
After Theisen washers.........	11.9	15.0	13.9	16.5	17.7	14.8	14.9	12.10
Barometer, inches of mercury......	29.34	29.37	29.44	29.45	29.42	29.41	29.45	29.37

TABLE 3 COMPOSITION OF GAS FROM INDIVIDUAL FURNACES

Averages

Blast Furnace No.	CO_2	CO	H	$\frac{CO}{CO_2}$	B.t.u.	Product
1	4.36	33.71	3.41	7.75	120.4	Ferro-Silicon
2	13.47	26.34	4.43	1.95	96.7	Basic
3	14.98	23.97	4.43	1.60	91.4	Basic
4	13.91	24.99	4.10	1.79	94.1	Basic
5	14.17	25.61	3.85	1.81	95.5	Bessemer
6	13.65	25.32	4.26	1.85	95.7	Bessemer

TABLE 4 COMPOSITION OF MIXTURES OF GAS FROM VARIOUS FURNACES

Averages

Blast Furnace No.	CO_2	CO	H	$\frac{CO}{CO_2}$	B.t.u.	Product
1 and 2.............	8.92	30.02	3.92	4.85	108.5	....
1, 2 and 3............	10.60	28.01	4.09	2.65	102.8	....
2, 3 and 4............	14.12	25.10	4.32	1.80	94.1	Basic
1, 2, 3 and 4.........	11.68	27.25	4.09	2.33	100.6	....
2 and 3..............	14.23	25.15	4.43	1.81	94.0	Basic
1, 2, 3, 4, 5 and 6...	12.25	26.66	4.08	2.23	98.9	....

TABLE 5 AVERAGE COMPOSITION OF BLAST FURNACE GAS

At 62 Deg. Fahr. and 30 Inches Mercury

	Jan.	Feb.	Mar.	Apr.	May	June	Avg. Jan.-June
CO_2	13 26	13.38	11.53	12.43	13.10	13.20	12.82
CO	25 61	25.50	28.10	26.67	26.56	26.50	26.49
H	2.99	3.95	2.92	3.16	3.74	3.89	3.44
CH_4	0.21	0.23	0.24	0.21	0.22	0.18	0.215
Computed B.t.u.	93.01	95.70	100.50	98.81	97.70	98.20	97.32
Ratio $\frac{CO}{CO_2}$	1.93	1.90	2.43	2.15	2.02	2.00	2.07
Heat value per cu. ft. by Calorimeter B.t.u.	93.45	96.10	101.00	98.08	98.32	97.99	97.49

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg. July-Dec.	Avg. Jan.-Dec.
CO_2	14.10	12.50	10.03	11.96	13.88	13.75	12.53	12.67
CO	25 90	27.30	29.80	26.02	24.70	25.85	26.54	26.51
H	3.86	4 06	3.77	3.45	3.59	3.98	3.78	3.57
CH_4	0.17	0.18	0.19	0.21	0.19	0.15	0.18	0.196
Computed B.t.u.	95 70	101.40	108.70	102.90	86.70	95.80	98.40	97.90
Ratio $\frac{CO}{CO_2}$	1.83	2.18	2.98	2.17	1.78	1.88	2.12	2.09
Heat value per cu. ft. by Calorimeter B.t.u.	95.50	101.60	107.40	103.10	92.90	94.60	99.20	98.30

APPENDIX NO. 3

DESCRIPTION OF METHODS AND INSTRUMENTS USED IN OBTAINING DATA UPON THE PERFORMANCE OF THE GAS CLEANING PLANT

Temperatures. The temperature of the gas entering the cleaning plant is measured and automatically recorded by a Bristol pyrometer. Readings of the gas temperature are taken by the operators every three hours, after the dry cleaning plant, after the wet scrubbers, and before and after the Theisen washers, the last temperature being also recorded by a Bristol recording thermometer. Temperature readings are further taken at the inlet and outlet of each gas holder. All thermometers have the Fahrenheit scale and are permanently installed in the pipe lines. The water temperatures are read every three hours at the pump suction, after each wet scrubber and after the Theisen washers. For the purpose of comparison the temperature of the atmosphere near the washer building is simultaneously recorded. Portable thermometers with the Fahrenheit scale are used for measuring water temperatures.

2 *Pressures.* Readings are taken by the operators every three hours, by means of ordinary U-tubes, of the gas pressure in inches of water at the following places: at the point where the gas enters the cleaning plant, between the *wet* scrubbers, and before and after the Theisen washers. In addition, the pressure of the raw gas at the main water seal, and of the fine gas after the Theisen washers, is continuously recorded by Bristol pressure gages. For convenience of observation all instruments indicating and recording gas and water pressures, temperatures and venturi meter pressure differences, are arranged on a *gage* board (Fig. 1)installed in the Theisen washer building. On the same gage-board the telephone gongs and the optical indicators showing the position of the two gas-holder bells are mounted. By a simple system of contacts each gas-holder bell, while descending, closes five different electric circuits, and causes incandescent lights to burn corresponding to its different positions. Thus a white light burns when the holder is in its top position; a green light appears when the holder bell has descended 7 ft.; one red light, indicating danger, corresponds to a 14-ft. immersion of the holder bell, and two, and at last three, red lamps show that the bell has fallen 21 ft. and 28 ft. respectively, and is nearing its bottom position. When the three red lights burn the gas holder is practically empty. Similar optical indicators are installed in the electric power and gas blowing-engine houses, so that the engine operators can independently observe the position of the gas holders at any time.

3 *Power Consumption.* As all Theisen washer and pump motors are operated by 440-volts alternating current reduced in special transfomers from 2200 volt, 25 cycle, 3 phase current generated in the electric station, an integrating kilo-

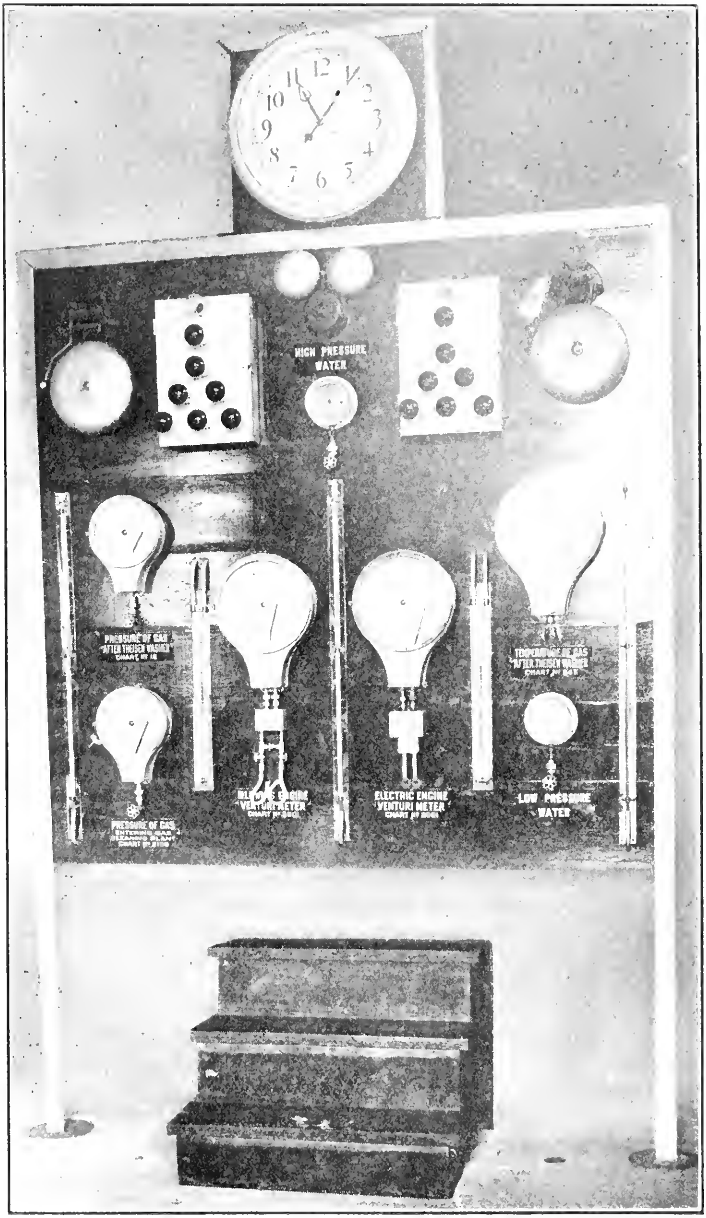


FIG. 1 GAGEBOARD IN THEISEN WASHER BUILDING.

watt meter was installed at the main switchboard to measure the combined power consumed by all gas cleaning plant motors. Unfortunately, the motor-driven air compressors for starting the gas engines are on the same line, so that the power for two 50-h.p. motors is included in the meter readings; but since each air compressor is running only about one hour each day, the error is believed to be of little weight. However, it must be kept in mind that on this account the recorded power consumption of pumps and Theisen washers is higher than the actual values. A portable ampere meter for use in the Theisen washer building can easily be attached to each motor and read by the operator every three hours, and the readings are recorded in the daily report sheets. These ampere meter readings give the only indication of the load carried by each Theisen washer. As all washers operate in parallel, one machine, by a slight misadjustment of the inlet and outlet gate valves, may handle more gas, thus carrying more load, and cleaning its share of the gas to a less extent than the other washers. The ampere meter will indicate such an inequality in the load distribution, and the operators have orders to keep the ampere readings on all washers in operation fairly uniform, by proper adjustment of the gate valves. The indications of the ampere meter, averaged for each month, are used to divide the power charges in proper proportion between the pumps in the preliminary washing plant and the Theisen washers.

4 *Water Consumption.* The amount of water consumed each minute in the gas-washing plant is measured by overflow weirs at the settling tank. A hook gage gives directly the number of gallons of water per minute falling over the weir so that the operator reads the water quantity as easily as a thermometer. The settling tank has two compartments, so that the water from the wet scrubbers can be turned into one, while the Theisen waste water is flowing into the other compartment. Gates make it possible to reverse these flows and to shut off each settling tank for cleaning. The amount of water allowed at each wet scrubber and Theisen washer, originally apportioned by means of calibrated barrels, is adjusted in practice by estimating the relative quantity basing the estimate on the thickness of the stream at each Theisen water inlet and at the wet scrubber overflow. The water used for gas-washing purposes is waste cooling water from the blast furnaces, formerly discharged into the sewer but now collected and piped to the Theisen washers under its natural head, while another part is lifted on top of the wet scrubbers by two centrifugal pumps of 2,000,000-gal. capacity each. These pumps receive the water under 30 ft. head and deliver it at a pressure of 80 ft. for distribution through the sprinkler system.

5 *Dust and Moisture.* Gas engine builders usually specify the amounts of dust and moisture which should not be exceeded for safe operation. Recent specifications call for blast furnace gas containing not more than 0.02 grains of flue dust and not over 10 grains of moisture per cu. ft., at 62 deg. fahr. and 30 in. mercury. With an efficient, modern gas-cleaning plant it is not difficult to meet these conditions, as is shown in the paper. Dust and moisture determinations are made in the gas laboratory, and recorded on daily chemical report blanks (Fig. 6 in the body of the paper). The amount of dust is determined in dry cleaned gas, clean gas and fine gas, and occasionally in the atmosphere, while moisture determinations are made in clean and in fine gas. For purposes of comparison the moisture in the atmosphere, as determined at the dry-blast

plant, is also recorded. Results are given in grains per cubic foot of standard gas, and by a simple calculation the efficiency of the wet scrubbers and of the secondary washing plant can be determined each day.

6 While frequently tried, it has been found impossible to make dust determinations in raw gas, which give more than a general idea of the efficiency of the dry cleaning plant. The difficulty is that the raw gas frequently carries larger particles of dirt, which obstruct the sample pipe and clog the dust filter before a gas sample of sufficient size for correct determination can be secured.

7 A series of tests extending over eight days was made in August 1908, with the regular dust filter apparatus then in use, but since no results were obtainable, a long glass tube open at both ends and filled with dry calcium chloride was then weighed and attached to the gas main in place of the dust filter. After passing several cubic feet of gas, the glass tube was taken off, closed at both ends and weighed, the difference in weight giving the total amount of dust and moisture. The amount of dust was determined by drying and weighing again as the difference between the second and third weighings. This apparatus was found to be a little more satisfactory, as larger samples could be taken, but gradual filling of the pipe with dust made the accuracy of the results very doubtful. The size of the gas sample secured never exceeded 6 cu. ft., with an average of about 2 cu. ft.

8 Tests made in August 1907 gave similarly unreliable results, as the amount of dust in raw gas, according to these determinations, varied from 0.18 grains per cu.ft.at 2 p.m., August 7, to 563.19 grains per cu. ft.at 4.30 p.m. August 29. Such extreme variations are improbable, and as the results obtained cannot represent a fair average, raw gas dust tests were discontinued as of questionable value.

9 The method and the instrument used for the determination of dust in clean and fine gas were developed by Messrs. Wm. Brady and L. A. Touzalin. The Brady filter (Fig. 2) consists essentially of a brass cylinder provided with inlet and outlet and supporting the filter itself, which is an ordinary 94 x 33 mm. Soxhlet extraction shell. The brass cylinder is of such diameter that an annular space of about $\frac{3}{16}$ in. is formed between its inner surface and the paper filter. The filtering shell is fastened and held tightly in place without the aid of gaskets, by wedging its open end between the tapering cylindrical faces of the brass shell and the brass nozzle, as shown in the illustration. This method of fastening has the additional advantage that for a distance of about one-half an inch from the edge, the Soxhlet shell is protected from dust deposits so that the filter can safely be handled after the experiment. The brass nozzle forming the inlet of the apparatus is provided with inside threads so that it can be screwed to a sampling pipe. Its inside surface is perfectly smooth, without ledges or places for the accumulation of dust. A brass nut holds the three parts of the instrument in place. The apparatus may be used in any position, but the preferred arrangement is horizontal.

10 When the gas to be filtered contains moisture the filtering device must be heated to about 110 deg. cent. by any suitable means, but preferably by surrounding the brass shell with an electrically heated sleeve as shown in Fig. 3, which represents the sampling pipe, Brady filter, moisture tubes and gas meter assembled ready for use. The nipple on the outlet end of the brass cylinder is threaded so that it can be removed and replaced by aluminum

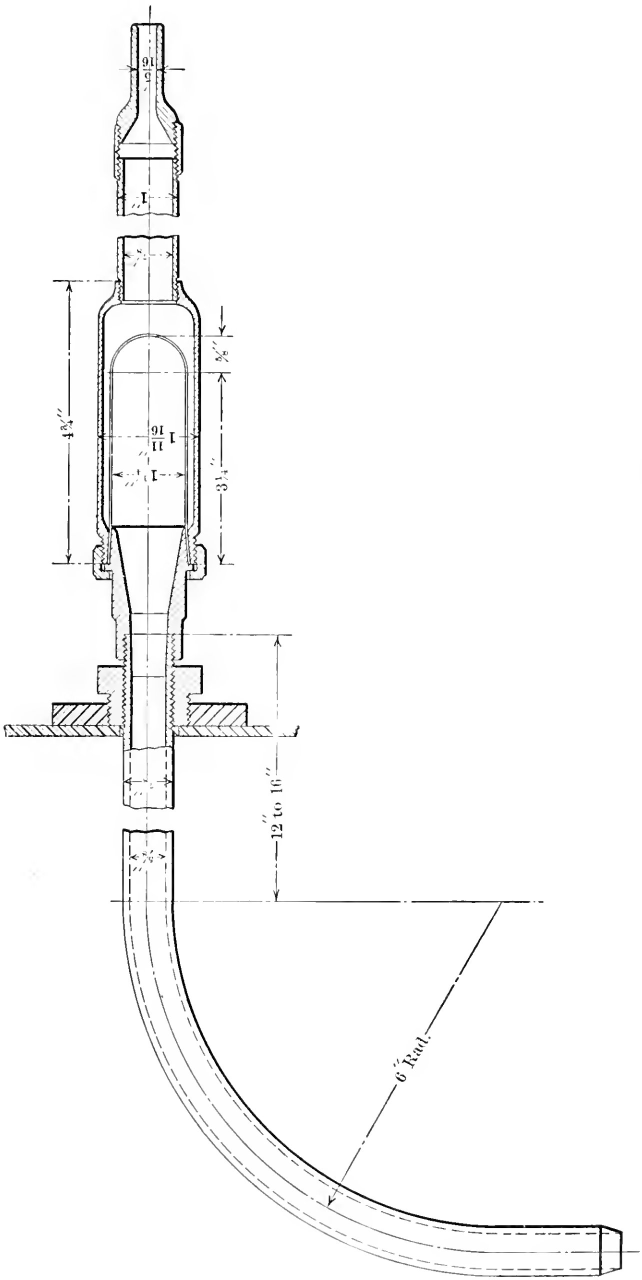


FIG. 2 SECTION OF BRADY DUST FILTER

tubes filled with a dehydrating agent such as calcium chlorid, in case it is desired to determine the moisture in the gas.

11 The Brady dust filter was chosen for use as standard instrument on account of its advantages over other methods. It is very simple, easily assembled and taken apart, perfectly tight, and it fulfills the requirement that the gas issuing from the sample pipe should pass over very little surface before being filtered. The principal advantage, however, is the use of a strong cylindrical filter which resists the gas pressure much better than the thin sheet of filter paper used in other instruments. The Soxhlet shell maintains a porous condition even though much fine dust has been deposited owing to the formation of concentric layers of dust and their subsequent cracking by the action of gravity and slight jarring. Gas samples of twice the size permissible in other instruments can be passed through the Brady filter. Fig. 4 shows five Brady filter shells after use for determination of dust at the main water seal, before and after the wet scrubbers, after the Theisen washers, and after the power station gas holder. The feature of keeping the filter porous for large samples is noticeable, particularly in the shell on the extreme left.

12 Whenever determinations of dust and moisture, or both, are desired, the instrument must be placed as close as possible to the pipe where the sample is to be taken. The sampling pipe used, shown in Fig. 3, consists of a ½-in. brass pipe curved with a radius of not less than 6 in. and smoothly polished on the inside. It is inserted in the gas flue, if possible on a horizontal diameter at least 15 ft. away from any bend or obstruction, to a distance of one-fourth to one-third of the diameter. The inlet opening is reduced to a sharp edge, so that there is as little local disturbance at that point as possible. The question of the proper form of sampling pipe was decided in favor of the curved pipe, against the straight pipe with standard 4-in. insertion in the gas main. Experiments were made at various times to determine the amount of flue dust, by simultaneously using both forms of sampling pipe inserted at practically the same place in the gas flues.

13 A comparison of the results of these tests shows plainly the difference in the effect of straight and curved sampling pipes on the size of the gas sample, which generally speaking is larger with the curved pipe. This advantage is, however, of secondary importance, compared with the material increase in the dust contents recorded by sampling the gas with curved pipes. This increase is particularly noticeable in testing dry cleaned gas, and shows that the heavier particles of dust cannot easily be induced to change their direction of travel to enter the straight sample pipe at right angles, but pass by the opening, which is parallel with the gas stream. The difference in results averages nearly 100 per cent in favor of the curved sampling pipe.

14 In the clean gas tests this difference is considerably less marked and the average size of the gas sample obtained is even smaller, while the amount of dust recorded when using the curved sampling pipe is only 8½ per cent larger, because the dust remaining in clean gas is of much finer quality and of less specific gravity, so that the particles will much more easily change their direction of travel. No difference at all, however, can be observed when dealing with fine gas. The averages of two series of tests coincide exactly, and only slight deviations are noticeable in the individual readings. The average size of the gas sample taken with the curved pipe is 14 per cent larger then the sample

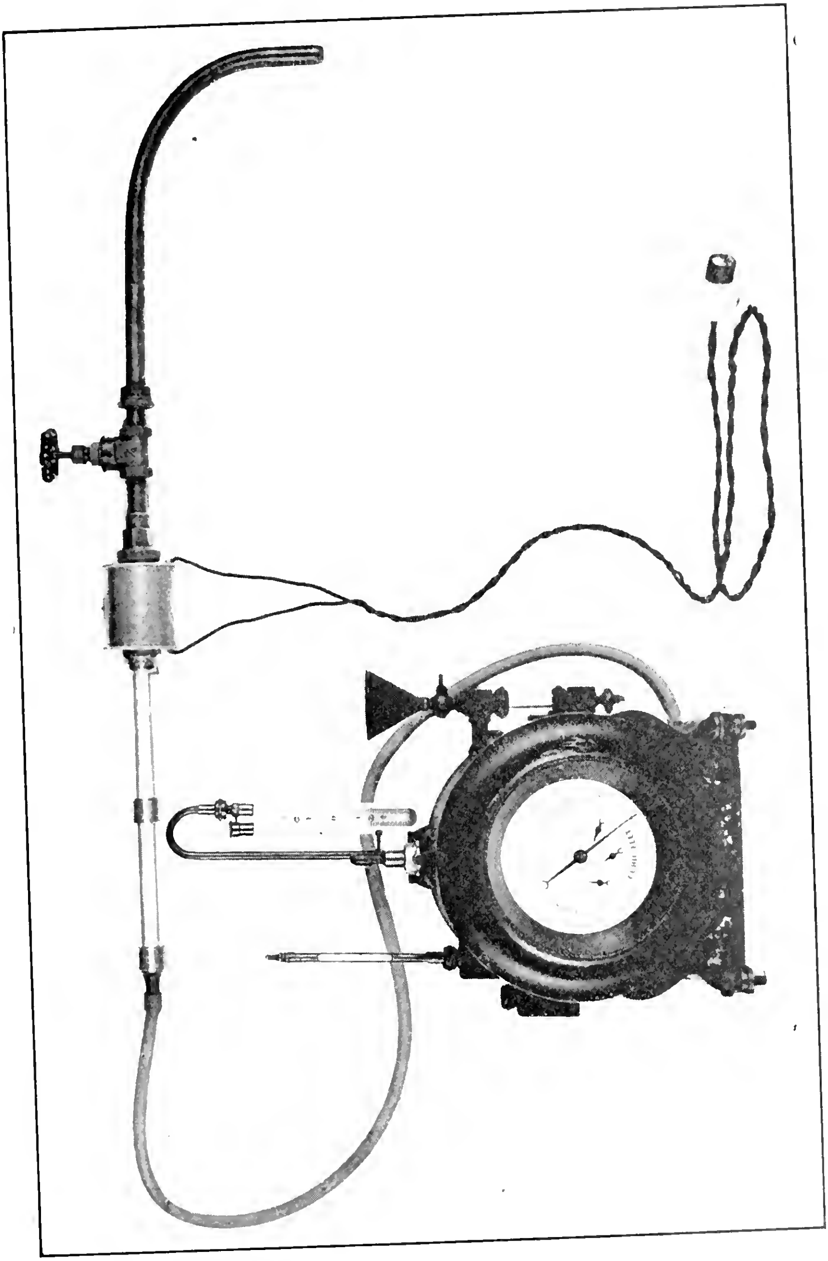


FIG. 3 BRADY FILTER, SAMPLING PIPE AND GAS METER

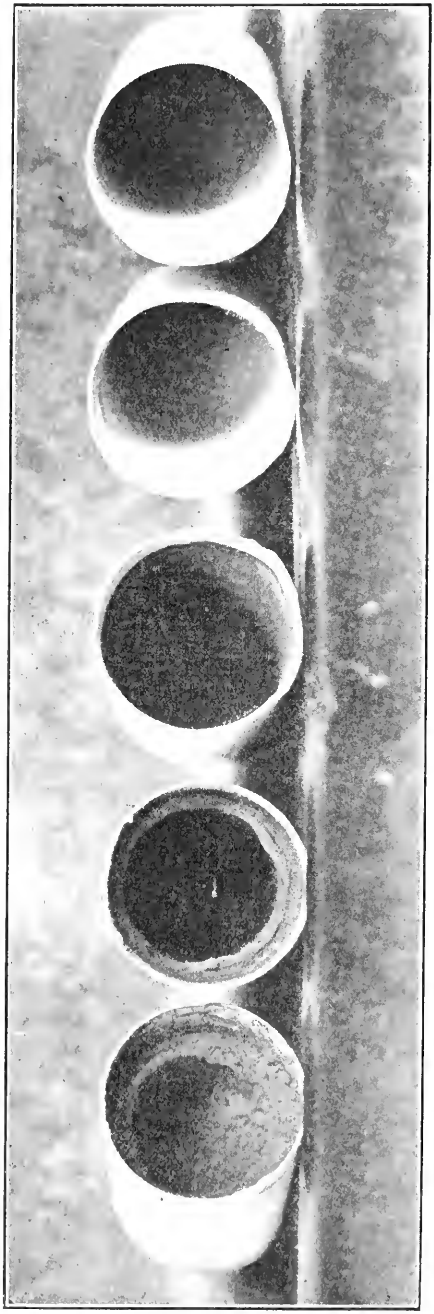


Fig. 4 Brady Filter Shells After Use

obtained with the straight sampling pipe. This experience is valuable as it shows that dust determinations in fine gas are very much less influenced by variations in the method of sampling, which further suggests that results will not be materially affected by variations in the instruments and methods used for dust determinations in fine gas.

15 As the original gas pressure is usually—in fine gas always— sufficient to cause the gas to flow through the filter, an aspiration of the sample is unnecessary. The determination is made as follows: The Soxhlet shell is first dried and weighed in a glass weighing bottle, then inserted into the brass shell of the apparatus, and the parts tightly connected. A meter reading is taken after the instrument is connected to the sample pipe and the gas is turned on. The dust contained in the gas sample is deposited in the Soxhlet shell, while the moisture is driven over into the aluminum tubes containing anhydrous calcium chlorid, and connected in series. They are capped and weighed before the experiment and their increase in weight represents the moisture in the volume of gas passed through the apparatus, while the increase in weight of the shell after drying gives the amount of dust carried in the gas sample. For dust determinations from 30 to over 200 cu.ft. of gas are passed, depending on conditions of pressure and locality, while for moisture determinations only from one to five cu. ft. are used. Usually one or several moisture tests may be made while one dust test is being run, simply turning off the gas for a moment when the aluminum tubes are inserted and again when they are withdrawn. Readings of the meter and of the gas conditions such as temperature and pressure must of course be made at the beginning and end of each test. All results of dust and moisture tests are calculated to grains per cubic feet of standard gas.

16 The application of two Brady filters permits continuous determination, a feature of great importance in gas power plants since it permits uninterrupted surveillance of the gas cleaning plant and of its efficiency. Continuous dust determinations are being made every day except Sunday, by sampling dry cleaned gas, clean gas and engine gas. A Brady filter is started at each place at 8.30 a.m., and the gas is allowed to pass until 4.30 p.m., when the Soxhlet shell is removed and a new one inserted, which is in continuous use from 5.00 p.m. until 8.00 a.m. the following morning. The average size of sample for day and night runs respectively, is from 60 to 90 cu.ft. of dry cleaned gas, 80 to 160 cu.ft. of clean gas, and 120 to 200 cu.ft. of engine gas. It is evident that such large accumulative samples must very nearly represent a true average of the amount of dust contained in the gas. Occasional dust and moisture determinations usually practiced in the majority of plants are of comparatively little value, as they do not give the true average conditions of the gas. Comparisons of results obtained at different gas-cleaning plants cannot and should not be made and credited, unless all instruments, methods, size of samples, duration of tests, etc., are identically the same. Standardization of the method of determining dust and moisture in industrial gases would benefit the gas engine industry at large, and the method used at this plant, which has been thoroughly and continuously tried under all conditions, is worthy of consideration as a basis for standardization.

APPENDIX NO. 4

RESULTS IN DETAIL OF OPERATION OF GAS-CLEANING PLANT

TABLE 1 HEAT LOSS OF GAS BY RADIATION

Monthly Averages

1908	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
Gas cleaned, cu. ft. per min.	14,020	12,850	16,950	18,070	17,690	13,090	15,420
Temperature of gas at main water seal, deg. fahr.	426	410	303	312	299	329	346
Temperature of gas to scrubber No. 1, deg. fahr.	210	196	202	168	150	133	177
Difference:							
Loss by radiation, deg. fahr.	216	214	101	144	149	196	169
Reduction in per cent	50.7	52.2	33.3	46.1	49.8	59.5	48.8

TABLE 2 WET SCRUBBER EFFICIENCY

Monthly Averages

1909	Jan.	Feb.	March	April	May	June	Avg. Jan.-June
Flue dust in dry cleaned gas, gr. per cu. ft	0.4772	0.4787	1.2951	1.0335	1.1172	1.0804	0.9137
Flue dust in clean gas, gr. per cu. ft	0.0766	0.1224	0.2238	0.2178	0.2146	0.2389	0.1825
Difference	0.4006	0.3563	1.0713	0.8157	0.9026	0.8415	0.7312
Per cent removed by wet scrubbers	84.0	74.5	82.8	79.0	80.8	77.8	79.7

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg. July-Dec.	Avg. Jan.-Dec.
Flue dust in dry cleaned gas, gr. per cu. ft.	0.7990	1.6124	4.0940	2.8794	2.4004	1.1188	2.1506	1.5330
Flue dust in clean gas, gr. per cu. ft	0.1316	0.3669	0.8257	0.9882	0.2539	0.1786	0.4541	0.3183
Difference	0.6674	1.2455	3.2683	1.8912	2.1465	0.9402	1.6965	1.2147
Per cent removed by wet scrubbers	83.5	77.4	79.9	65.7	89.6	84.2	78.8	79.3

TABLE 3 GAS AND WATER TEMPERATURES

MONTHLY AVERAGES

1909	Jan.	Feb.	March	April	May	June	Avg. Jan.-June
Temperature of gas to wet scrubber No. 1, deg. fahr	123.20	126.00	161.00	152.00	163.20	172.00	149.60
Temperature of gas to Theisen washers, deg. fahr	41.40	44.00	49.60	55.50	63.80	74.20	54.70
Temperature of gas to gas holder, deg. fahr	40.10	43.00	44.10	52.50	64.20	69.70	52.30
Temperature of water supply, deg. fahr	43.80	45.00	44.20	52.30	62.80	71.70	53.30
Waste, wet scrubber No. 1, deg. fahr	59.20	63.00	62.50	67.20	77.00	84.80	68.90
Waste, wet scrubber No. 2, deg. fahr	43.30	44.00	46.80	52.70	63.20	72.90	53.80
Temperature of air, deg. fahr	27.90	31.00	37.10	46.40	56.90	65.10	44.10

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg. July-Dec.	Avg. Jan.-Dec.
Temperature of gas to wet scrubber No. 1, deg. fahr	169.20	173.60	150.60	159.50	119.30	86.70	143.30	145.70
Temperature of gas to Theisen washers, deg. fahr	76.50	79.10	72.70	61.80	61.70	52.80	67.40	61.10
Temperature of gas to gas holder, deg. fahr	79.10	80.90	72.30	61.00	61.10	42.00	54.40	56.60
Temperature of water supply, deg. fahr	74.70	78.60	72.80	63.70	64.50	46.20	66.70	60.00
Waste, wet scrubber, No. 1, deg. fahr	89.00	96.70	95.50	94.70	92.50	88.30	92.80	80.80
Waste, wet scrubber, No. 2, deg. fahr	76.70	81.50	77.10	64.90	65.40	52.70	67.70	61.70
Temperature of air, deg. fahr	83.40	85.20	74.60	60.80	58.80	31.20	65.60	54.90

TABLE 4 EFFICIENCY OF SECONDARY WASHING PLANT

MONTHLY AVERAGES

1909	Jan.	Feb.	March	April	May	June	Avg. Jan.-June
Flue dust in clean gas, gr. per cu. ft	0.0766	0.1224	0.2238	0.2178	0.2146	0.2389	0.1825
Flue dust in fine gas, gr. per cu. ft.	0.0036	0.0057	0.0044	0.0059	0.0067	0.0067	0.0055
Difference	0.0730	0.1167	0.2194	0.2119	0.2079	0.2322	0.1770
Per cent removed by refining	95.4	95.4	98.0	97.4	96.6	97.3	97.0

TABLE 4—CONTINUED.

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg. July-Dec.	Avg. Jan.-Dec.
Flue dust in clean gas, gr. per cu. ft.	0.1316	0.3669	0.8257	0.9882	0.2539	0.1786	0.4541	0.3183
Flue dust in fine gas, gr. per cu. ft.	0.0057	0.0058	0.0080	0.0074	0.0069	0.0093	0.0061	0.0058
Difference	0.1259	0.3611	0.8177	0.9808	0.2470	0.1693	0.4480	0.3125
Per cent removed by refining	95.6	98.5	99.0	99.1	97.5	95.0	98.7	98.1

TABLE 5 DETERMINATION OF FLUE DUST AT DIFFERENT POINTS OF SECONDARY CLEANING PLANT

GRAINS PER CUBIC FOOT

1910	Turn	After wet scrubbers	Before Theisen washers	After Theisen washers	After gas holder
March 21	night	0.1496	0.1091	0.0024	0.0024
March 22	day	0.1681	0.1468	0.0066	0.0051
March 22	night	0.1647	0.1292	0.0045	0.0042
March 23	day	0.1773	0.1563	0.0091	0.0094
March 23	night	0.1185	0.1145	0.0062	0.0065
March 24	day	0.1566	0.1489	0.0058	0.0058
March 24	night	0.1456	0.1371	0.0066	0.0064
March 25	day	0.1568	0.0983	0.0067	0.0061
March 25	night	0.1474	0.1258	0.0064	0.0057
March 26	day	0.1425	0.1078	0.0037	0.0029
Average		0.1527	0.1274	0.0058	0.00545

Average amount removed
- By clean gas main ....0.0253 grains per cu. ft.
- By Theisen washers ....0.1216 grains per cu. ft.
- By fine gas main and gas holder ....0.00035 grains per cu. ft.

Average absolute efficiency of
- Clean gas main....................16.56 per cent.
- Theisen washers....................95.45 per cent.
- Fine gas main and holder....................6.03 per cent.

The average total efficiency of the secondary cleaning plant was 96.43 per cent, in which the three above factors participated as follows:
- Clean gas main....................16.56 per cent.
- Theisen washers....................79.64 per cent.
- Fine gas main and gas holder.................... 0.23 per cent.

Total ....96.43 per cent.

TABLE 6 DUST IN COMBUSTION AIR

Date	Wind	DAY TURN: Temp of Air Deg. Fahr.	Barometer	No. cu. ft. sample	Dirt grams per cu.	Weather	NIGHT TURN: Temp. of Air	Barometer	No. cu ft. sample	Dirt grams per cu. ft.
7-12-09	W.	78	29.21	74.13	0.0052	Part Cloudy	70	29.31	81.88	0.0043
7-13-09	W.	76	29.19	95.57	0.0032	Part Cloudy	71	29.26	57.59	0 0037
7-14-09	S. W.	80	29.27	124.51	0.0013	Wind blowing hard	73	29.28	102.84	0.0052
7-15-09	W.	84	29.28	126.41	0.0048	Part cloudy	76	29.28	129.11	0.0036
7-16-09	N. W.	80	29.34	88.69	0.0004	Wind hard	86	29.40	95.46	0.0005
7-17-09	N. W.	84	29.39	145.82	0.0004	Clear	..	......	......	....
Average				109.19	0.00255				93.37	0.00346

TABLE 7 ANALYSES OF DUST DEPOSIT ON GAS AND AIR DAMPERS OF GAS ENGINE NO. 1

Sample February 1909	Gas Damper 1	Gas Damper 2	Air Damper 3	Air Damper 4
Silica	19.60%	22.50%	32.40%	23.80%
Alumina	12.07	20.19	6.50	11.30
Iron	6.95	6.37	11.12	12.03
Manganese	2.52	2.62	1.04	1.15
Lime	32.74	23.00	5.84	5.37
Magnesia	3.43	3.38	0.92	0.95
Volatile	17.89	17.38	37.84	39.85

TABLE 8 ANALYSES OF FLUE DUST REMOVED FROM BLAST FURNACE GAS AT DIFFERENT STAGES OF GAS CLEANING

March 1908	SiO_2	Al_2O_3	Fe	CaO	MgO	Fix C.	Sul.	Phos.	Mang.	Vo.
From main water seal (deposit)	10.30	4.60	48.85	2.46	0.30	15.52	....	0.067	0.53	....
From collecting main after dry cleaning plant (deposit)	11.44	4.45	42.86	3.15	0.68	10.28	0.202	0.079	0.80	7.28
From No.1, wet scrubber (sediment)	14.58	5.45	43.09	2.75	0.78	9.17	0.288	0.095	0.60	4.17
From No. 2, wet scrubber (sediment)	18.26	5.85	38.20	4.74	1.40	8.54	0.192	0.097	0.47	5.08
From Theisen washers (sediment)	22.93	7.94	26.06	7.60	1.61	11.47	0.314	0.119	1.08	6.73

TABLE 9 ANALYSIS OF FLUE DUST REMAINING IN BLAST FURNACE GAS AT DIFFERENT STAGES OF GAS CLEANING

MARCH 1909

Location of Brady filters	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Mn.	Vol.
At main water seal..........	12.19%	5.93%	52.39%	4.70%	0.97%	1.16%	22.32%
Gas entering wet scrubber No. 1	11.37	5.21	52.55	3.76	0.86	0.83	25.18
In clean gas main.............	21.14	11.53	28.35	9.56	1.94	2.46	24.31

TESTS ON WET SCRUBBERS

1 Tests were made on October 27, 1908, to determine the cooling and condensing effect of the wet scrubbers. The temperature of the water and gas entering and leaving the washers were taken with accurate thermometers.

TABLE 10 WET SCRUBBER TEST

Time	Temperatures							Quantities			
	Water				Gas			Gas	Water		
	Scrubbers				Scrubbers			cu. ft. per min.	gal. per min.		
	Inlet 1 and 2	Outlet 1	Outlet 2	Outlet 1 and 2	Inlet 1	Outlet 1	Outlet 2		no. 1	no. 2	total
10.50	63.0	80.0	64.0	73.0	157.0	62.8	60.0	17,000	....		1,380
11.00	62.8	77.5	63.0	71.5	156.0	62.8	60.0	17,150	....		1,375
11.10	63.0	77.5	63.2	72.0	156.0	62.8	60.0	17,350	....		1,375
11.20	63.0	76.5	63.5	71.5	155.0	62.8	60.0	17,150	....		1,375
11.30	62.8	77.2	63.0	71.5	155.0	62.8	60.0	17,150	....		1,375
Average....	62.9	77.74	63.34	71.9	155.8	62.8	60.0	17,160	816	560	1,376
2.55	63.6	85.5	63.0	77.0	180.0	64.8	62.0	23,100	....		1,225
3.05	63.8	85.5	63.0	76.5	177.0	64.8	62.0	23,400	....		1,275
3.15	63.8	85.5	63.0	76.0	175.0	64.8	61.5	23,100	....		1,225
3.25	63.5	85.0	63.0	76.5	175.0	64.3	61.5	23,250	....		1,290
3.35	63.5	87.0	63.2	77.0	176.0	64.3	61.5	23,100	.....		1,260
Average ...	63.64	85.7	63.04	76.6	176.6	64.5	61.7	23,190	752	503	1,255

The total amount of water from both washers was measured by the weir, and the amounts passing through each washer were calculated from the final temperatures. The gas was measured by venturi meter. The temperature of the atmosphere was 45 deg. fahr. Two tests of 40 minutes each were made on the same day. The readings and averages are given in the table.

2 The total heat absorbed in the first scrubber during the first test was 100,912 B.t.u. per min., of which 31,205 B.t.u. is accounted for in the loss of sensible heat in the gas. On the second test the total heat absorbed was 137,874 B.t.u. per min., of which 50,848 B.t.u. is accounted for by the loss of sensible heat. From the following calculations the amount of vapor condensed per cu. ft. of gas at 64 deg. was found to be 27.4 grains in the first, and 25.2 graids in the second test, or an average of 26.3 grains.

First Test:

Washer 1, temperature of entering gas, 155.8 deg.; leaving gas, 62.8 deg.

Density of gas = 0.0815

Specific heat = 0.24

Cu.ft. of gas per min. = 17.160

Sensible heat lost by gas:

$17.160 \times 0.0815 \times 0.24 \times (155.8 - 62.8) = 31{,}205$ B.t.u. per min.

Heat absorbed by water:

$816 \times 8\frac{1}{3} \times (77.74 - 62.90) = 100{,}912$ B.t.u. per min.

100,912 B.t.u. − 31,205 B.t.u. = 69,707 B.t.u.

Average latent heat of vapor from 155.8 deg. to 62.8 = 1037 B.t.u.

$$\frac{69{,}707}{17{,}160 \times 1037} = 0.00392 \text{ lb. or } 27.4 \text{ gr. of vapor condensed per cu. ft. of gas at 64 deg.}$$

Second Test:

Sensible heat lost by gas:

$23{,}190 \times 0.0815 \times 0.24 \times 112.1 = 50{,}848$ B.t.u.

Heat absorbed by water:

$752 \times 8\frac{1}{3} \times 22.06 = 137{,}874$ B.t.u.

173,874 B.t.u. − 50,848 B.t.u. = 87,026 B.t.u.

Average latent heat from 176.6 to 64.5 deg. = 1029 B.t.u.

$$\frac{87{,}026}{23{,}190 \times 1029.7} = 0.003605 \text{ lb. or } 25.2 \text{ gr. vapor condensed per cu. ft. gas at 64 deg.}$$

3 Since the average temperature of the gas leaving the first scrubber was about 64 deg., the amount of moisture remaining in the gas was about 6.6 grains; this added to 26.3 grains condensed gives 32.9 total grains of moisture per cu. ft. in dry cleaned gas. This represents a dewpoint of about 117 deg. or about 31 per cent saturation at the average initial temperature of 166 deg. Later tests with wet and dry bulb thermometers in the gas mains showed dewpoints varying from 104 deg. to 114 deg. for an average gas temperature of 170 deg. The results of these tests indicate the reducing effect which the washing of the gas has on the moisture. While by these calculations the amount of moisture in the dry cleaned gas was found to be about 33 grains per cu. ft. in October 1908, moisture determinations with Brady filters made on July 14, 15 and 16, 1909, gave very similar results. It will be noted that the test figures fairly coincide with the calculated values.

1908, moisture determinations with Brady filters made on July 14, 15 and 16, 1909, gave very similar results. It will be noted that the test figures fairly coincide with the calculated values.

TABLE 11 MOISTURE TEST IN DRY CLEANED GAS

Date	CO_2	CO	H	CH_4	B. t. u	$\frac{CO}{CO_2}$
July 14 Gas analysis	14.8	25.5	3.0	0.1	91.8	1.72
Grains of moisture per cu. ft.						34.124
Temperature at meter, deg. fahr.						84
Barometer, inches of mercury						29.27
Temperature in gas main, deg. fahr.						192
Pressure in gas main, inches of water						9.5
July 15 Gas analysis	13.8	25.7	4.0	0.1	95.3	1.86
Grains of moisture per cu. ft.						41.7453
Temperature at meter, deg fahr.						85
Barometer, inches of mercury						29.68
Temperature in gas main, deg. fahr.						156
Pressure in gas main, inches of water						6.5
July 16 Gas analysis	13.1	26.1	3.5	0.2	96.1	1.99
Grains of moisture per cu. ft.						38.421
Temperature at meter, deg. fahr.						83
Barometer, inches of mercury						29.36
Temperature in gas main, deg. fahr.						190
Pressure in gas main, inches of water						10
Average moisture, gr. per cu. ft.						38.1

APPENDIX NO. 5

METHOD USED FOR MEASURING AND RECORDING GAS CONSUMPTION

The following description of the method used for measuring and recording the gas consumption was contributed by C. J. Bacon, Mem. Am. Soc. M. E.

2 The amount of gas consumed by the blowing engines at the blast furnaces and the power engines in the electric station, is measured by venturi meters one in the 54-in. main to the blowing engines and another in the 60-in. main to the power engines. The 60-in. meter was installed first and tested by volumetric measurements as hereinafter described. The 54-in. meter was subsequently constructed with the same proportions, and as the only difference is in the size no tests have been thought necessary. These meters are of much the usual form, except that certain liberties were taken in the design to simplify the shop work; the throat section of each being a straight cylinder connected to the small ends of the upstream and downstream cones without rounding at the intersections; and there was a similar omission of curvature at the connection between the approach section of 5ft. pipe and the large end of the upstream cone. Although it was realized that these departures from theoretically perfect design were likely to introduce more or less error due to eddy currents, nevertheless in view of the facility with which the accuracy could be determined by means of the gas holder, the somewhat irregular construction was allowed to stand. The absence of test data on meters of this size made tests advisable regardless of how nearly perfect the shape and construction might be.

3 By referring to Fig. 23*b* of the paper, it will be seen that the 60-in. meter has an over-all length of 53 ft. 1 in., and consists of an up-stream cone 11 ft. 6 in. long and having openings 60 in. and 20 in. in diameter, a straight cylindrical throat section of cast iron 20 in. in diameter by 15 in. long, and a downstream cone 39 ft. long, likewise with openings 60 in. and 20 in. in diameter. The up-stream cones are made of plate, with butt-joints and countersunk rivets inside to reduce friction. A cylindrical casting 16 in. long by 60 in. in diameter and containing an annular pressure chamber, is inserted between the straight-approach pipe and the upstream cone. A similar pressure chamber surrounds the throat. Twelve 3/16-in. holes communicate to each of the chambers the pressures existing within the meter at those points. The characteristic equation for flow of gas in venturi tubes[1] was used in the calibration of this meter.

4 A number of carefully conducted tests have been made at various times to determine the meter coefficient, utilizing the 100,000 cu. ft. gas holder as a means of volumetric measurement. This holder is located about 260 ft. from

[1]See The Flow of Fluids in a Venturi Tube, by E. P. Coleman, Transactions, vol. 28, 1907 p. 483, for the derivation of this equation.

the meter, and is provided with a combination of water-sealed valves such that the flow of gas to and from the holder may be controlled at will. The horizontal area of the holder was accurately determined by measurement of diameters, and a vertical scale of feet and tenths was marked on the outside to permit of determination of the rate of rise of the holder. Observations were taken of

A gas pressure in the upstream chamber.
B difference in pressure between upstream and throat chambers.
C temperature of gas at meter and holder.
D analysis of gas including water vapor contents.
E barometric pressure.
F gas pressure at inlet to holder.

From these data and the dimensions of the meter, values may be assigned in the above-mentioned equation of flow. It is worthy of especial note that the ratio of specific heats for the mixture of gas and aqueous vapor is in this case 1.38, the use of it in the formulæ, however, does not result in an appreciably lesser flow than the use of 1.408, the commonly accepted value for air. Without burdening this paper with the actual data and computations, the net average results of 17 separate holder tests at various rates of flow shows a meter coefficient of 0.91, which is taken to mean that the actual flow is 91 per cent of the theoretical flow.

5 This determination of meter coefficient was made more as a matter of scientific interest than as a necessity, since working curves showing the relation between the difference in upstream and throat pressure and volume of gas at prevailing temperatures and pressures, could have been constructed from test data alone. The meter coefficient, however, being available, it was made use of in connection with the theoretical formula in preparing the curves in Fig. 35 of the paper, from which the volume of gas, reduced to standard conditions of 62 deg. fahr. and 29.92 in. barometer, may be determined for prevailing temperatures and meter readings. For these curves the absolute pressure of gas in the main is taken as 29.5 in. mercury, which is the sum of the average upstream pressure and the average barometer at this locality.

6 Daily records of flow of gas are obtained by means of a Bristol differential pressure recorder, located in the Theisen washer building about 250 ft. away from the meter and connected to upstream and throat chambers by two lines of pipe. Comparison of readings at the meter with the recorder shows no error due to the long connecting pipes. The curves of Fig. 2 are used in conjunction with these daily meter charts to obtain the average rate of flow for each day, which with the calorific value, the kilowatt output of the generators and the generator efficiency, gives the data required for computing the daily average thermal efficiency at the engine shaft. The chart shown in Fig. 36 of the paper represents a flow of 22.044 cu. ft. per min. Other observations and computations for that day were as follows:

B.t.u. per cu. ft. at 62 deg. fahr.	87.1
Average load, kilowatts	7306
B.t.u. per kw-hr	15761
B.t.u. per b.h.p-hr. at 96 % generator efficiency	11311
Thermal efficiency at shaft	22.5

The monthly averages of these daily data, and the results for the year 1909 are shown in Fig. 38 of the paper.

7 Questions are often raised regarding the amount of dust deposited in meters for blast furnace gas. The 60-in. meter has been examined at six-month intervals. The first inspection showed a slight accumulation of moist dust at and near the throat, but not in sufficient quantity to affect the results appreciably; at the second examination no dirt was found; at the third a considerable coating of dirt was found and was cleaned out, unfortunately without accurate measurement of the average thickness. As a means of determining the effect of the reducing diameter on the flow of gas, a comparison was made of the average thermal efficiency for a week preceding and a week following the cleaning as follows:

Week preceding cleaning....................................16.9 per cent
Week following cleaning..... .... 19 0 per cent
Reduction of flow..11 per cent

As far as known no change occurred at the engines to affect the efficiency; consequently, since the flow through the meter varies directly as the area, the reduced diameter due to dust was $\left(\frac{16.9}{19.0}\right)^{\frac{1}{2}}$ x 20 in. = 18.8 in. Therefore the average thickness of the coating was approximately 0.6 in.

8 The cause of this unusual deposit is ascribed to one of the furnaces making special irons, ferrosilicon and spiegel, during the latter part of August and the entire months of September and October 1909, or about 68 days during which the amount of dust found in the raw gas was excessive, as explained in par.73 of the paper. On this basis it is assumed that the deposit began late in August and continued at uniform rate through October, when the error amounted to a maximum of 11%. Suitable corrections were made on the monthly averages shown in the tables and charts. To prevent a repetition of the accumulations of dust in the venturi meter a system of spray nozzles (shown in Fig. 23*b* of the paper) was installed, for flushing the meter throat thoroughly with high-pressure water.

A COMPARISON OF LATHE HEADSTOCK CHARACTERISTICS

By Prof. Walter Rautenstrauch, New York
Member of the Society

The discovery of the properties of high-speed steels, and the large amount of experimental data available on the performance of these steels on various classes of materials, have urged the designer to attempt to incorporate in machine tools such characteristics as will adapt the machines to the most efficient use of the new steels. There exist at present many machines which are intended to meet the new standard of performance, and it will be interesting to examine the results of the attempts which have been made to meet the new conditions and to note the direction in which they have tended. There are many bases on which machine tools may be compared, and no single machine will ever prove best from all points of view; as the limits of this paper prevent the discussion of all these points, one of several possible standards will be adopted as a basis for comparison, and the results will be interesting though not conclusive.

2 Since the new steels will take heavier cuts than is possible with the carbon steels, and still retain their durability, a standard of comparison will be established on the basis of those characteristics of speed and torque in a lathe headstock which permit the most economic removal of shavings from a given class of material, viz., soft and medium steels. A comparison of the speeds and torques actually obtainable in any machine with the standard characteristics will serve as a means for judging the efficiency of the headstock in this particular. In this connection the method devised by Dr. J. T. Nicolson, of Manchester, is employed, the foundations of which are as follows:

3 Since the volume of metal removed by a lathe tool in a given time is a product of the area of cut and the speed of cutting, the weight removed in one minute will be equal to the area of cut in square inches times the speed of cutting in inches per minute times the weight of

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the metal per cubic inch. The force on the tool has been determined experimentally[1] to be approximately proportional to the area of the cut, the torque required to take any size cut is equal to the force on the tool times the radius of the work, and the speed at which the cut can be taken on any diameter of work depends on the spindle speed which can be obtained. These facts, together with the relations which have been established between possible maximum cutting speed and area of cut on different materials,[2] show that in any machine a definite relation must exist between the spindle speeds and the accompanying torques obtainable, that the machine may be adaptable to efficient weight removal on all diameters of any material.

4 The results of the experiments made by the Manchester Association of Engineers and the Berlin Section of the Verein Deutscher Ingenieure, have been used by Dr. Nicolson to derive equations expressing the approximate relation between the area of cut and the maximum cutting speed. The duration of cut was not less than 20 minutes, without injury to the tool. The following result was obtained for the materials in question (medium and soft steel):

$$V = \frac{1}{a} + 15 \quad \text{[1]}$$

where V = cutting speed in feet per minute.
a = area of cut in square inches.

This equation, therefore, serves to determine the cutting speed at which it is possible to operate on this material without injury to the tool, when taking a cut of a given size.[3]

5 To establish a basis for determining the spindle speeds and torques required to remove the maximum weight of shavings on all diameters of work, it is necessary to determine the average area of cut which a lathe of given size should be expected to take. This was accomplished by Dr. Nicolson through correspondence with lathe builders, and the conclusion reached[4] was that the following rule met with wide acceptance for the machining of mild steel forgings:

$$a = \frac{S^2}{25{,}600} \quad \text{[2]}$$

where a = area of cut in square inches.
S = swing of lathe in inches.

[1] Transactions, vol. 25, p. 656.
[2] Report of Manchester Association of Engineers, October 24, 1903.
[3] The Engineer (London), April 7, 1905.
[4] The Engineer (London), April 28, 1905.

6 If the above relations are true, namely, that the maximum possible cutting speed for mild steel varies with the area of cut as expressed in Equation 1; that the average area of cut on this material which a lathe of any given swing should be expected to accommodate is as given in Equation 2; and that the force in the tool varies directly as the area of the cut (for mild steel the force on the tool is approximately 100 tons for each square inch of area cut): then the following basis may be established for the design of, say, an 18-in. lathe capable of removing the maximum weight of shavings in a given time on all diameters of work.

standard area of cut on all diameters

$$= \frac{S^2}{25{,}600} = \frac{18^2}{25{,}600} = 0.0126 \text{ sq. in.}$$

$$\text{Force on tool} = 100 \times 2000 \times 0.0126 = 2520 \text{ lb.}$$

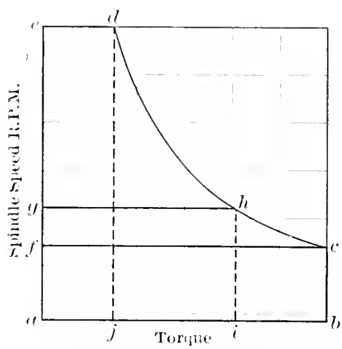

Fig. 1 Ideal Speed-Torque Diagram

$$\text{torque on work of face plate diameter} = 2520 \times \frac{3}{4} = 1890 \text{ ft. lb.}$$

$$\text{maximum cutting speed at which cut may be taken} = \frac{1}{a} + 15$$

$$= \frac{1}{0.0126} + 15 = 94\tfrac{1}{2} \text{ ft. per min.}$$

revolution of spindle required for this cutting speed on work of face

$$\text{plate diameter} = \frac{94\frac{1}{2}}{\frac{3}{4} \times 2\pi} = 20 \text{ r.p.m.}$$

7 The maximum torque required of the lathe will on this basis be equal to 1890 ft. lb., while the minimum spindle speed necessary to give the maximum cutting speed on this area of cut at face plate diameter is 20 r.p.m. When the standard area of cut is taken on a smaller diameter the resulting torque will obviously be less. It will be

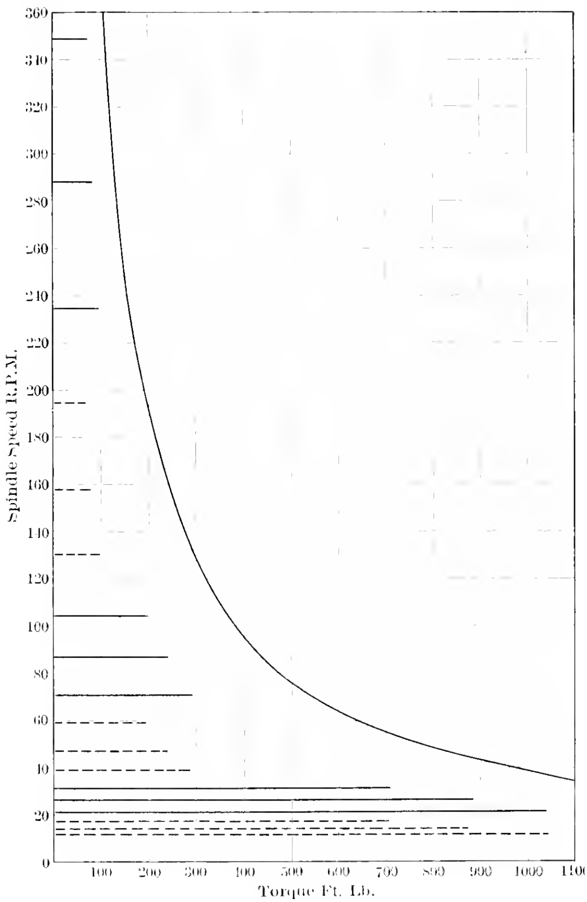

FIG. 2 ACTUAL SPEED-TORQUE DIAGRAM

necessary, however, to increase the spindle speed of the machine, if that surface speed is to be maintained, which is desirable for the most efficient use of the tool and to maintain constancy of volume removed.

8 Since the spindle speed for these conditions will vary inversely as the diameter of the work, and the torque directly as the diameter

of work, it will be obvious that when the problem is to remove the maximum weight of shavings on all diameters of work, the product of speed and torque should be a constant. The highest spindle speed for which the lathe should be designed will depend on the smallest diameter of work which the lathe can economically handle, and the maximum cutting speed desirable on this diameter. On the basis that the least diameter is $\frac{S}{16}$, and that a cutting speed of 120 ft. per min. should be provided, the maximum spindle speed should be

$$Ng = \frac{12 \times 120}{\frac{S}{16}\pi} = \frac{7200}{S} \text{ (approx.)}$$

TABLE 1 (FIG. 2) 18-IN. LATHE

COUNTERSHAFT SPEEDS 195 AND 235 R.P.M.; CONES 13 IN., $10\frac{7}{8}$ IN., $8\frac{3}{4}$ IN. DIAMETER; FIRST BACK-GEAR RATIO 3 31 to 1; SECOND BACK-GEAR RATIO 10.95 to 1, BELT $3\frac{1}{2}$ IN.; ASSUMED BELT PULL 50 LB. PER INCH OF WIDTH

Spindle Speed r.p.m.	Torque ft. lb.	Spindle Speed r.p.m.	Torque ft.lb.
12 00	1040	71.00	314
14 40	865	87.30	261
17.80	700	105.40	212
21.46	1040	131.25	95
26.40	865	158.17	79
31.87	700	195.00	64
39.65	314	235.00	95
47.80	261	289.00	79
58.90	212	349.00	64

For the case of an 18-in. lathe this would result in a maximum spindle speed of 400 r.p.m.

9 In accordance with the above analysis, the ideal characteristic to which the design should tend is as shown in Fig. 1. The abscissæ represent torques, and the ordinates revolutions of the spindle. For the 18-in. lathe the dimensions of the diagram shown in Fig. 1 are

$ab = fc = 1890$ ft. lb.
$af = bc = 20$ r.p.m.
$ae = jd = 400$ r.p.m.
$aj = ed = 95$ ft. lb.

10 Since the product of speed and torque should be a constant, for the reasons previously explained, an equilateral hyperbola be-

tween the points d and c completes the construction of the ideal diagram. Accordingly, af is then the speed at which the spindle should run that the standard area of cut may be taken at its proper speed on work of face-plate diameter, and fc is the corresponding torque permitting this area of cut to be taken. Likewise, if the diameter of work is less than face-plate diameter, and since the torque varies directly as the diameter of work for a given area of cut, the torque for diameter of work equal to $S\frac{ai}{ab}$ and standard area of cut, is gh, while the spindle speed required to give the appropriate cutting speed is ag.

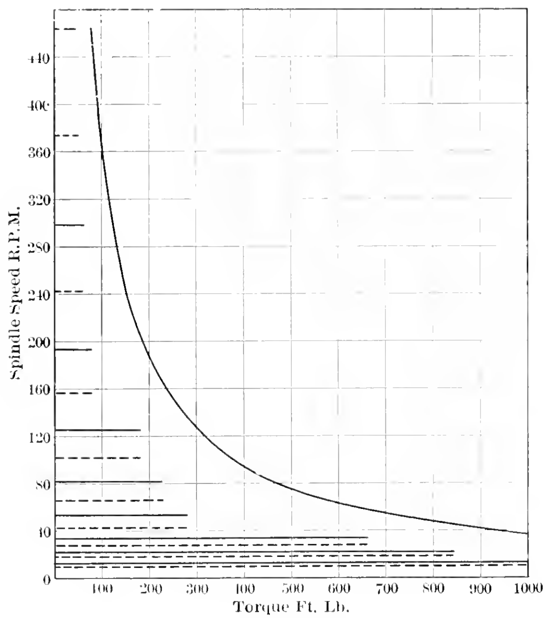

FIG. 3 ACTUAL SPEED-TORQUE DIAGRAM

11 It will be apparent that this diagram may be used in two ways; first, as a means for determining the proper relations which should exist between spindle speeds and torques when a lathe of any size is to be designed for conditions as defined above (to remove the maximum weight of shavings in a given time on all diameters of work of any given material); second, as a means for determining the extent to which the speeds and torques of a lathe already designed correspond to the standard established. In this latter connection it will also be

possible to determine whether or not any speeds, with their corresponding torques, might be omitted without hindering the weight-removing capacity of the headstock.

12 To illustrate the manner in which the diagram may be used as a standard for comparison, Figs. 2 and 3 are presented. In these figures are shown the speeds and torques obtainable in two lathes of recent manufacture, made by different firms. The data for the determination of the speeds and torques, which were obtained from the manufacturers' catalogues, are given in Tables 1 and 2.

13 On the basis that these lathes should be capable of operating on mild steel, with an area of cut on all diameters as determined in the above analysis and up to the maximum cutting speed which the

TABLE 2 (FIG. 3) 18-IN. LATHE

COUNTERSHAFT SPEEDS 196 TO 234 R.P.M.; CONES 12 IN., $9\frac{7}{8}$ IN., $7\frac{3}{4}$ IN. DIAMETER; FIRST BACK GEAR, RATIO 3.66 TO 1; SECOND BACK GEAR, RATIO 13.5 TO 1; BELT 3 IN.; ASSUMED BELT PULL 50 LB. PER INCH OF WIDTH

Spindle Speed r.p.m.	Torque ft.lb.	Spindle Speed r.p.m.	Torque ft.lb.
11.6	1012	82.0	226
14.4	1012	102.0	177
18.0	835	126.0	177
22.3	835	157.0	75
27.8	655	195.0	75
34.5	655	243.0	61.6
42.7	274	300.0	61.6
53.0	274	375.0	48.5
66.0	226	465.0	48.5

durability of the tool steel will permit, it will be noted that these designs are deficient; for example, if it were required to turn a piece of mild steel 9 in. in diameter, with a cut of 0.0126 sq. in. = $\frac{1}{8}$ in. x $\frac{3}{32}$ in. (approximately) the torque required would be

$$0.0126 \times 2{,}000{,}000 \times \frac{9}{2 \times 12} = 985 \text{ ft. lb.}$$

The lathe illustrated in Fig. 2 would have to take this on spindle speed 1 or 4. Speed 4 would give the highest cutting speed which would be

$$21.46 \times \frac{9 \times \pi}{12} = 50\tfrac{1}{2} \text{ ft. per min.}$$

But with the above area of cut a cutting speed of $94\frac{1}{2}$ ft. per min. would be possible under ideal conditions, hence the minimum time in

which one pound of shavings could be removed under the actual circumstances is about twice what it would be if the required torque were available at the maximum cutting speed.

14 Any number of examples could thus be worked out to illustrate the limits which the dimensions of this headstock impose on either the area or speed of the cut which can be taken on any diameter of work. The question may be asked, to what extent do each of these speeds, with their corresponding torques, contribute to the weight-removing capacity of the lathe, when operating on this material?

15 Referring to Fig. 1, it will be noted that the area $ab \times bc$ is the product of the torque and spindle speed and is

$$f\ a\ r \times \frac{V}{2\pi r} = \frac{f}{2\pi}\ a\ v = K\ a\ V$$

where

f = force on tool in pounds per square inch.
a = area of cut in square inches.
V = cutting speed in feet per minute.
r = radius of work in feet.

But the area of the cut times the speed of cutting is a measure of the volume of metal removed in a given time and hence a measure of the weight removed in a given time. Any condition, therefore, fixing the limits to the area and speed of cut which can be taken on any diameter of work will limit the maximum rate at which metal can be removed.

16 Let us determine, therefore, to what extent the gap between the speeds, and the departure of the torque from that which has been established as desirable at the different speeds, will effect the weight-removing capacity of the lathe. Let Fig. 4 represent the ideal torque-speed diagram for any lathe, established on the above basis, and ab and ac two spindle speeds actually obtainable with torques bd and ec respectively. Then with a speed of spindle ab and torque bd, the standard area of cut may be taken on work of diameter $S \frac{bd}{ag}$, where S is the swing of the lathe.

17 Suppose it is only necessary to take a lighter cut $\left(a = \frac{bj}{bd}\right)$ on the same diameter of work, can it be more economically removed by taking the full cut $\left(a = \frac{bj}{bd}\right)$ with the spindle speed ab or, neglect-

ing the time for resetting the tool, to use a still lighter cut with the spindle speed *ac* and go over the work twice to bring it to finished size? Also, up to what limit of area of cut will it be more economical to use the speed *ab* than *ac*?

18 Now the whole area of cut may be taken at the lower speed *ab*, for which the rate of weight removed is represented by $(bj \times jq)$, or it may be taken at the higher speed *ac* by going over the work twice, first with a depth of cut and feed, giving an area of cut equal to $a_s \frac{bx}{bd}$, and again with remaining depth of cut and a feed giving the same area of cut $a_s \frac{bx}{bd}$, required to bring the piece down to size.

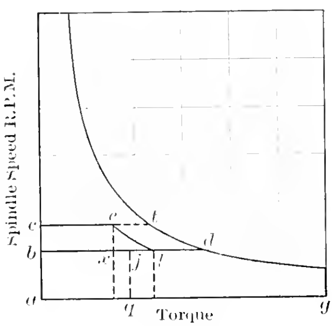

FIG. 4 IDEAL SPEED-TORQUE DIAGRAM

Neglecting for the present the time taken to reset the tool, it will be seen that the weight removed in the same time will be greater by going over the piece twice, each time with an area of cut equal to $a_s \frac{bx}{bd}$, and spindle speed *ac*, than by taking the cut of area $a_s \frac{bj}{bd}$ at the lower spindle speed *ab*.

19 To illustrate more specifically, suppose for example that *bd* represents the torque required to take the standard cut a_s on some given diameter of work, then *bj* would represent the torque required on the same diameter of work when the area of cut is not equal to the standard area but is equal to $a_s \frac{bj}{bd}$, since the ratio of the torques is equal to the ratios of the areas of cut on the same diameter of work.

If $a_s = 0.0126$ sq. in., $a_s \frac{bj}{bd} = 0.0084$ sq. in., $a_s \frac{bx}{bd} = 0.0063$ sq. in., and $ab = 30$ r.p.m., $ac = 50$ r.p.m., then the rate of weight removal when taking the area of cut $a_s \frac{bj}{bd}$ at the spindle speed ab is proportional to $0.0084 \times 30 = 0.252$, while if the area of cut $a_s \frac{bx}{bd}$ is taken at the spindle speed ac the rate of weight removal is proportional to $0.0063 \times 50 = 0.315$. The above condition will be true up to such areas of cut on the given diameter which, when multiplied by the lower spindle speed, will give a rate of weight removal greater than 0.315. This limit of area of cut may be conveniently determined by drawing an equilateral hyperbola through *e* and letting it cut *bd* at *l*.

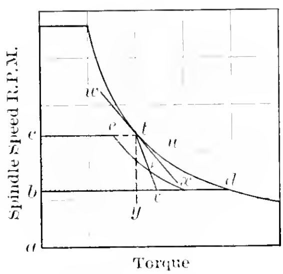

FIG. 5 IDEAL SPEED-TORQUE DIAGRAM

Areas of cut from $a_s \frac{bl}{bd}$ to a_s can be more economically removed for the given diameter of work at the lower speeds, while areas of less than $a_s \frac{bl}{bd}$ can be more economically removed by taking the lighter areas of cut $a_s \frac{bx}{bd}$ at the higher spindle speed and going over the work twice to bring it to size. Therefore, the efficiency in weight removed of this range of speeds and torques, compared to the ideal case where all speeds and torques, define within the area *bctd* are available, is represented by the ratio

$$\frac{\text{area } bcel}{\text{area } bctd}$$

In case the areas of cut from $a_s \frac{bx}{bd}$ to $a_s \frac{bl}{bd}$ can not be taken on the diameter in question at the higher spindle speed because the resulting surface speed is too great, the above statement is not true. A few of the designs examined have been checked in this manner and found to come within the limit just defined.

20 No allowance, however, has been made for the time required to run the carriage back and reset the tool. It will be seen that as the limiting area $a_s \frac{bl}{bd}$ is approached, the time saved on the use of the lower speed in place of the higher becomes less. Accounting for the time required to reset the tool for a second run, it will be noted that the limiting area is reached before $a_s \frac{bl}{bd}$. Just where the limit will be encountered it is impossible to determine except by empirical methods. Dr. Nicolson has ascertained that this limit may be approximately determined by the use of the following construction, irrespective of the type or design of the lathe.

21 Let Fig. 5 represent the conditions taken in Fig. 4. Construct a tangent ux to the hyperbola at t and drop the vertical ty. Bisect the angle between ux and ty by the line tv. The efficiency of this particular part of the headstock will be approximately represented by

$$\frac{\text{area } ceuxb}{\text{area } ctdb}$$

Areas of cut equal to and greater than $a_s \frac{bv}{bd}$ can be more economically taken on this diameter of work at the lower speed ab because of the difference in time required to handle the machine for the two cuts required to bring the piece to size.

22 This constructionis to be considered as a rough approximation only, and represents the facts as well as the conditions in the case will permit. This method of comparing the efficiency of a lathe with a predetermined ideal performance on any given material is due to Dr. J. T. Nicolson and Mr. Dempster Smith, to whom all credit should be given. The above method is useful in determining the adaptability of a lathe to meet only one of the many kinds of service in which the lathe may be employed and is not a final means for either justifying or condemning a lathe for general purpose work.

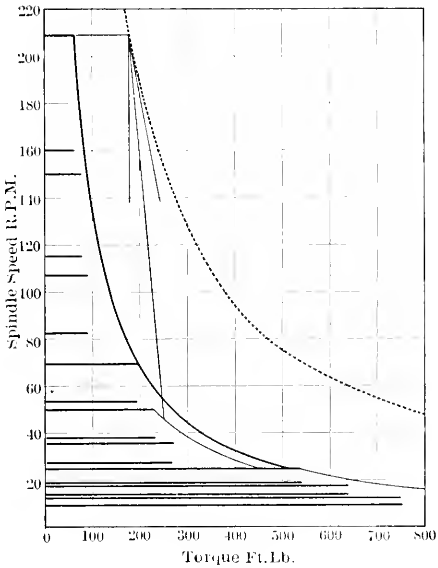

Fig. 6 16-In. Double Back-Geared Lathe

TABLE 3 (FIG. 6) 16-IN. DOUBLE BACK-GEARED LATHE

Cone Diameters $8\frac{1}{4}$ in., $9\frac{7}{8}$ in., $11\frac{1}{2}$ in.; Belt Width $3\frac{3}{4}$ in.; Countershaft Speeds 115 and 150 r.p.m. First Back-Gear Ratio 3 to 1; Second Back-Gear Ratio $8\frac{1}{3}$ to 1

Spindle Speeds r.p.m.	Torques ft.lb.	Spindle Speeds r.p.m.	Torques ft.lb.
9.87	748	50.00	231
12.85	748	53.50	193
13.80	642	69.60	193
18 00	642	82.50	90
19.20	537	107.00	90
25.00	537	115.00	77
27.50	270	150.00	77
35.73	270	160.00	65
38.33	231	209.00	65

The torques were computed on the basis of 50 lb. per inch of belt effective on the pulley surface. As a basis of the foregoing analysis, the lathe should be capable of the following:

Ng (greatest desirable spindle speed) = 450 r. p. m.
Ml (least desirable spindle speed) = $28\frac{3}{4}$ r. p. m.
Moximum desirable torque = 1366 ft. lb.

23 There is, however, one point of broad application which a speed torque diagram constructed according to the above basis will immediately bring out; that is, the uselessness of certain speeds, with their corresponding torques, possible in a given lathe on any class of work. As an illustration of how the relative merits of lathes of different make may be determined with reference to a common standard, 11 lathes selected from the catalogues of different builders have been used in the

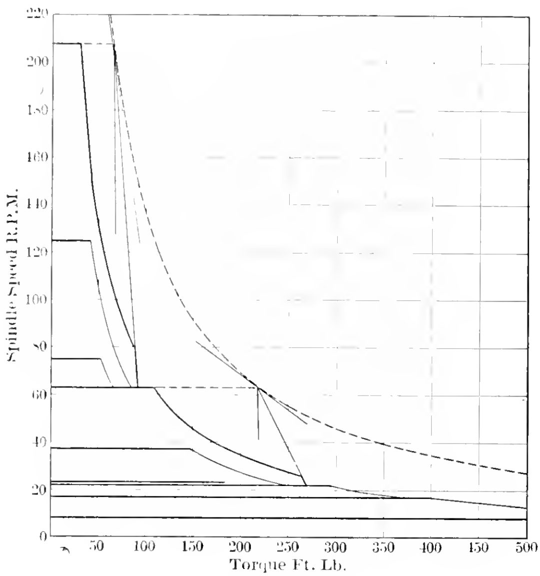

FIG. 7 16-IN. DOUBLE BACK-GEARED LATHE

TABLE 4 (FIG. 7) 16-IN. DOUBLE BACK-GEARED LATHE

CONE DIAMETERS 6 IN., 8 IN., 10 IN.; BELT WIDTH $2\frac{1}{2}$ IN.; COUNTERSHAFT SPEED 125 R.P.M.; FIRST BACK-GEAR RATIO $3\frac{1}{3}$ TO 1; SECOND BACK-GEAR RATIO $9\frac{1}{2}$ TO 1

Spindle Speeds r.p.m.	Torque ft.lb.
7.9	495
17.04	400
21.9	294
22.5	182
37.5	147
63.00	109
75.00	52
125.00	42
208.3	31

Ng = 450 r.p.m.; Nl = $28\frac{3}{4}$ r.p.m.; maximum torque = 1366 ft. lb.

construction of the following figures. In each case the data were obtained from the catalogues, or by correspondence with builders, and the possible speeds and torques determined. The data and results thus obtained are shown in Tables 3 to 13, the corresponding speed-torque diagrams being represented by Figs. 6 to 16.

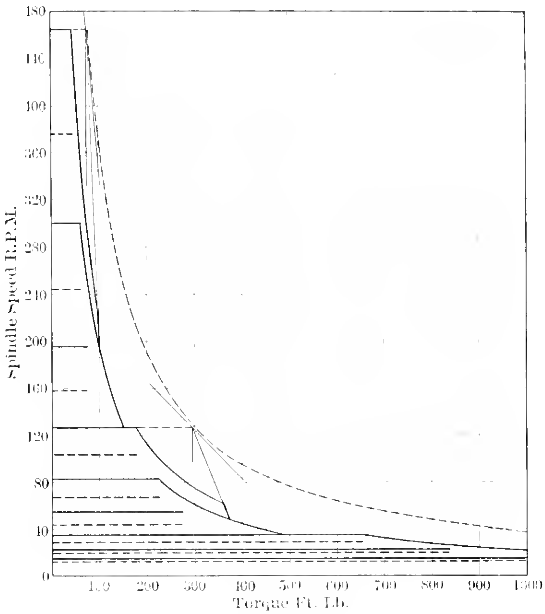

Fig. 8 18-in. Double Back-Geared Lathe

TABLE 5 (FIG. 8) 18-IN. DOUBLE BACK-GEARED LATHE

Cone Diameters $7\frac{3}{4}$ in., $9\frac{7}{8}$ in., 12 in.; Belt Width 3 in.; Countershaft Speeds 196 and 243 r.p.m.; First Back-Gear Ratio 3.66 to 1; Second Back-Gear Ratio 13.5 to 1

Spindle Speeds r.p.m.	Torques ft.lb.	Spindle Speeds r.p.m.	Torques ft.lb.
11.6	1012	82.0	226
14.4	1012	102.0	177
18.0	835	126.0	177
22.3	835	157.0	75
27.8	655	195.0	75
34.5	655	243.0	61.6
42.7	274	300.0	61.6
53 0	274	375.0	48.5
66.0	226	465.0	48.5

Ng = 400 r.p.m.; Nl = 20 r.p.m.; maximum torque = 1900 ft. lb.

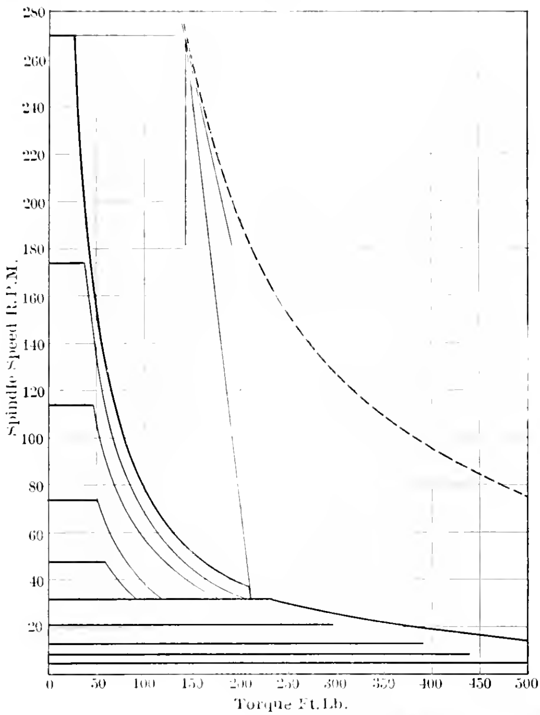

FIG. 9 18-IN. SINGLE BACK-GEARED LATHE

TABLE 6 (FIG. 9) 18-IN. SINGLE BACK-GEARED LATHE

CONE DIAMETERS $5\frac{1}{4}$ IN.; $6\frac{13}{16}$ IN., $8\frac{3}{8}$ IN., $9\frac{15}{16}$ IN., $11\frac{1}{2}$ IN.; BELT WIDTH $2\frac{1}{2}$ IN.; COUNTERSHAFT SPEED 125 R.P.M.; BACK-GEAR RATIO 8.44 TO 1

Spindle Speeds r.p.m.	Torques ft.lb.
5.70	500
8.75	437
13.50	390
20.60	300
32.00	231
48.00	60
74.00	52
114.00	46
174.00	36
270.00	27

N_g = 400 r.p.m.; N_l = 20 r.p.m.; maximum torque = 1900 ft.lb.

24 Among the facts brought out by this method of comparison of the adaptability of different makes of lathes to the performance of a standard task, there are two which are particularly striking. It will be noted in the first place that a considerable difference of opinion exists among the several builders, the characteristics of whose lathes

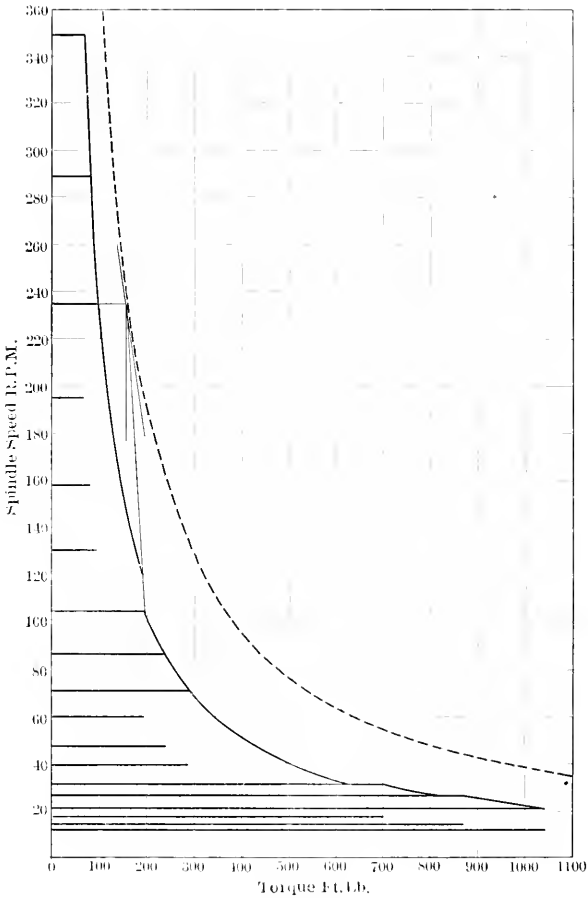

FIG. 10 18-IN. DOUBLE BACK-GEARED LATHE

are here illustrated, as to what constitutes a sufficient powering of the lathe to meet the demands of the high-speed steels, the number of speeds to be furnished, and the manner in which the speeds and torques should be spaced. If in reply to the questions of powering it is stated that the particular lathe in question is intended for taking

lighter cuts, which might be a proper basis for design under certain circumstances, it still remains to justify the manner in which the speeds and torques are spaced.

25 For example, take the case of the lathe represented in Fig. 6. For the single instance of having to turn a 9-in. piece of soft steel it

TABLE 7 (FIG. 10) 18-IN. DOUBLE BACK-GEARED LATHE

Cone Diameters $8\frac{3}{4}$ in., $10\frac{7}{8}$ in., 13 in.; Belt Width $3\frac{1}{2}$ in.; Countershaft Speeds 195 and 235 r.p.m. First Back-Gear Ratio 3.31 to 1; Second Back-Gear Ratio 10.95 to 1

Spindle Speeds r.p.m.	Torques ft.lb.	Spindle Speeds r.p.m.	Torques ft.lb.
12.0	1040	71.00	314
14.4	865	87.3	261
17.8	700	105.4	212
21.46	1040	131.25	95
26.4	865	158.17	79
31.87	700	195.00	64
39.65	314	235.00	95
47.8	261	289.00	79
58.9	212	349.00	64

Ng = 400 r.p.m.; Nl = 20 r.p.m.; maximum torque = 1900 ft. lb.

TABLE 8 (FIG. 11) 20-IN. ROUGHING LATHE

Cone Diameters $11\frac{1}{2}$ in. and 13 in.; 6-in. Double Belt; Countershaft Speeds 340 and 365 r.p.m.; First Back-Gear Ratio 3 to 1; Second Back-gear Ratio 6 to 1

Spindle Speeds r.p.m.	Torques ft.lb.	Spindle Speeds r.p.m.	Torques ft.lb.
50	1360	128	680
53	1210	137	605
64	1360	300	227
68	1210	323	202
100	680	384	227
107	605	412	202

Ng = 360 r.p.m.; Ml = 16 r.p.m.; maximum torque = 2666 ft. lb. Double belts are estimated as having 75 lb. per inch of width effective on pulley surface.

will be seen that the maximum area of cut that can be taken is limited to 0.01 sq. in., equivalent to a cut $\frac{1}{6}$ in. by $\frac{1}{16}$ in., and that the highest speed which the resulting torque of 750 ft. lb. will permit is 12.85 r.p.m., giving a cutting speed of 30 ft. per min. on this diameter. The cutting speed possible with soft steel on this area of cut is approximately 115 ft. per min. or if an area of cut of 0.0036 sq. in. is to be

taken on the same diameter, the highest spindle speed which the resulting torque of 270 ft. lb. will permit is 35.73 r.p.m., giving a cutting speed of 85 ft. per min. The cutting speed possible with this area of

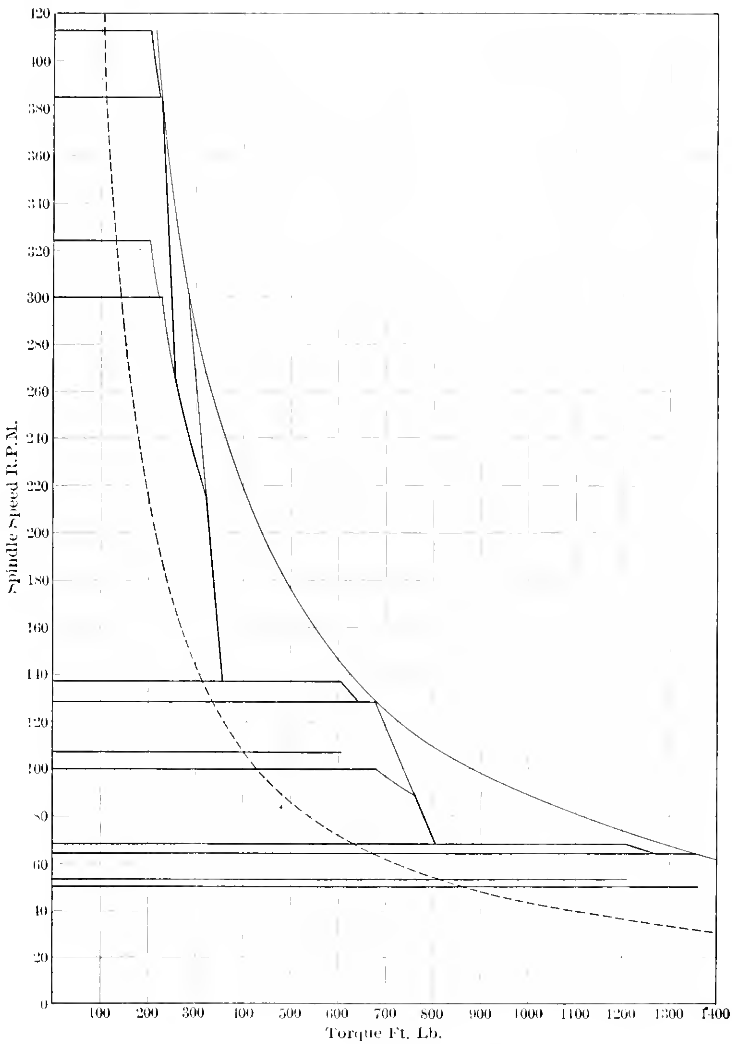

Fig. 11 20-in. Roughing Lathe

cut is above 200 ft. per min. For this size of work, then, the lathe is inefficient, or for efficient operation is limited to forms of work in which the cutting speeds and area of cut determined are the highest

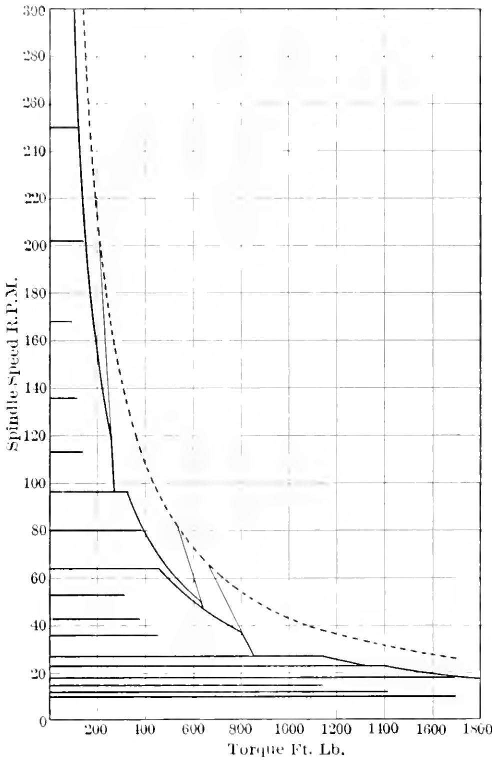

FIG. 12 21-IN. HEAVY-DUTY LATHE

TABLE 9 (FIG. 12) 21-IN. HEAVY-DUTY LATHE

CONE DIAMETERS $10\frac{3}{4}$ IN., $13\frac{3}{8}$ IN., 16 IN.; BELT WIDTH $4\frac{1}{2}$ IN.; TWO COUNTERSHAFT SPEEDS; FIRST BACK-GEAR RATIO 3.13 TO 1; SECOND BACK-GEAR RATIO 11.3 TO 1

Spindle Speeds r.p.m.	Torques ft.lb.	Spindle Speeds r.p.m.	Torques ft.lb.
12	1,700	64	470
10	1,420	80	394
15	1,150	96	320
18	1,700	113	150
23	1,420	136	126
27	1,150	168	102
36	470	202	150
43	394	250	126
53	320	300	102

Ng = 342 r.p.m.; Nl = 14 r.p.m.; maximum torque = 3087 ft. lb.

possible. In like manner, the limits of performance on any other diameter of work imposed by the torque-speed characteristics of the lathe, may be determined.

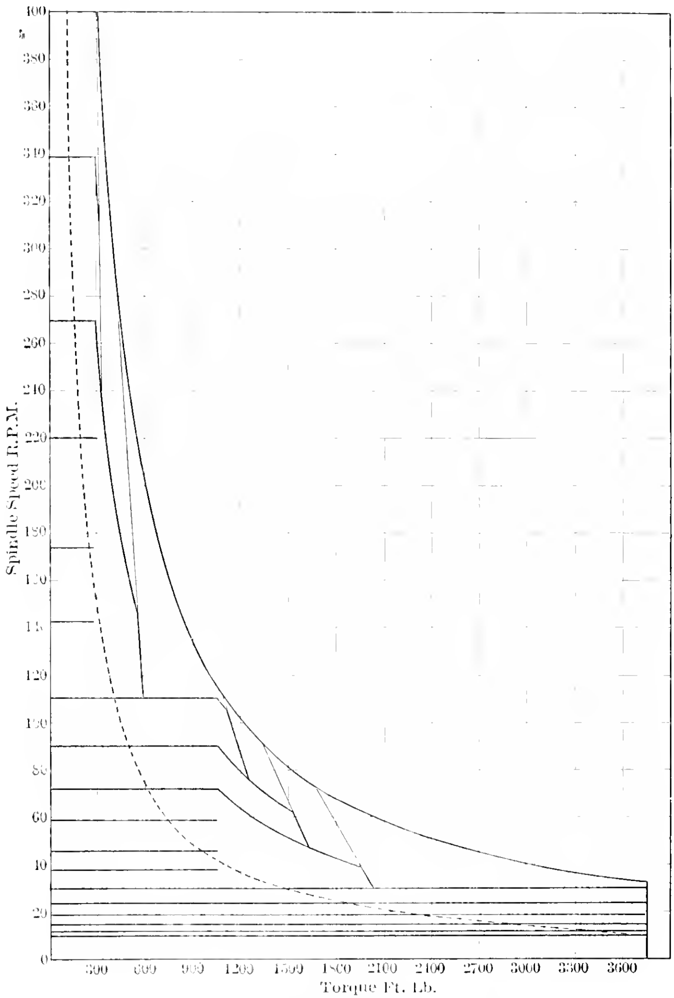

Fig. 13 24-in. Geared-Head Lathe

26 The extent to which the several speed-torque characteristics supplement one another is also very conveniently brought out in these diagrams. Again referring to Fig. 6, it will be noted that the con-

tribution of a number of the speed-torque combinations to the efficiency of the lathe for weight removal is brought into question, no matter what the standard of performance may be. If the foregoing analysis is rational, it indicates that the speeds 160, 150, 115, 107, 82, 73, 53, 50, 38, 35, 27, 19, 20, 18, 13.8, 12.85, and 9.87, with their accompanying torques are superfluous. Only upon a sufficient increase in the

TABLE 10 (FIG. 13) 24-IN. GEARED-HEAD LATHE

COUNTERSHAFT PULLEY 16 IN.; HEADSTOCK PULLEY 15$\frac{15}{16}$ IN.; COUNTERSHAFT SPEEDS 205 AND 250 R.P.M.; 6$\frac{1}{2}$-IN. DOUBLE BELT; FIRST BACK-GEAR RATIO 3.69 TO 1; SECOND BACK-GEAR RATIO 13 TO 1

Spindle Speeds r.p.m.	Torques ft.lb.	Spindle Speeds r.p.m.	Torques ft.lb.
10	3760	72	1066
12	3760	90	1066
15	3760	110	1066
19	3760	143	289
24	3760	174	289
30	3760	220	289
38	1066	270	289
46	1066	339	289
59	1066	414	289

Ng = 300 r.p.m.; Nl = 9.9 r.p.m.; maximum torque = 4608 ft. lb.

TABLE 11 (FIG. 14) 24-IN. GEARED-HEAD LATHE

COUNTERSHAFT PULLEY 16 IN.; HEADSTOCK PULLEY 16 IN.; BELT WIDTH 5 IN.; COUNTERSHAFT SPEED 400 R.P.M.; BACK-GEAR RATIO 5 TO 1

Spindle Speeds r.p.m.	Torques ft.lb.
21	3174
32	2083
40	1666
60	1111
107	623
160	417
200	334
300	223

Ng = 300 r.p.m.; Nl = 9.9 r.p.m.; maximum torque = 4608 ft. lb.

corresponding torque can each of these speeds add to the efficiency of the lathe. Considered on the basis of a dead investment alone, it will be seen that the equipment required to give the above speeds, which seem without justification, adds a useless burden to the product of this machine.

27 An examination of some of the following diagrams will reveal facts similar to those announced above. In those cases where two countershaft speeds are employed it will be noted that no increase in efficiency is had from this source. It is a pleasure, however, to note some exceptions, particularly in the case of Fig. 14. It will be observed that upon this basis of analysis there is a justification for each speed-torque characteristic. If any of the speeds were cut out, the efficiency

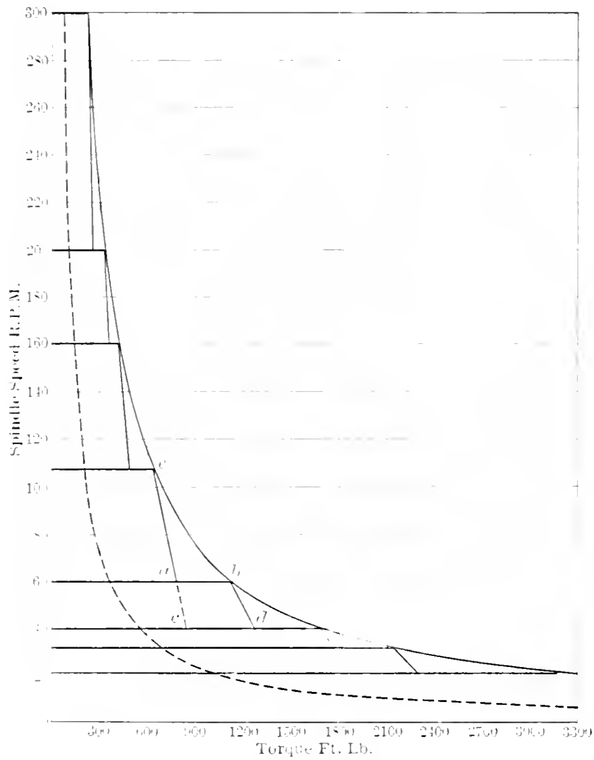

Fig. 14 24-in. Geared-Head Lathe

of the lathe would be reduced. With respect to the standard task used in this discussion, it will be noted that the removal of speed 60 from the headstock would reduce the efficiency by an amount proportional to the area *abcd*.

28 Another matter which appears in this connection is the relation of the efficiency to the number of speed-torque combinations, of which only eight are possible in this lathe. To what extent would the effi-

ciency be increased if eight additional speeds, with their accompanying torques, should be spaced halfway between the present combinations? The answer to this question would be obtained by the same method

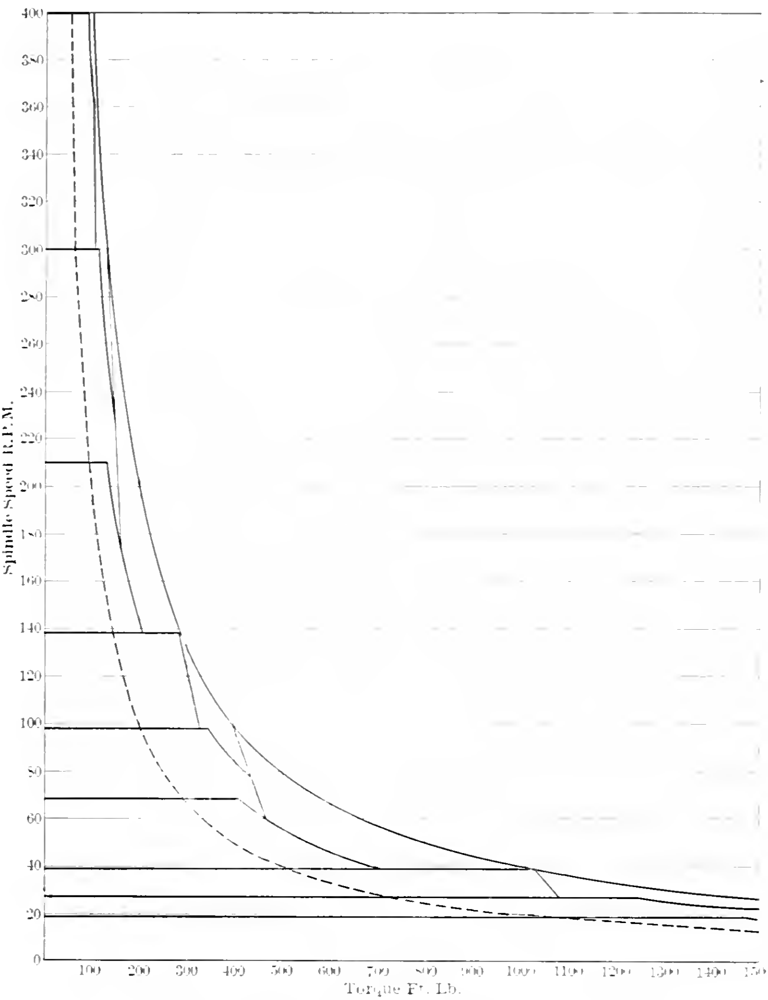

FIG. 15—24-IN. DOUBLE BACK-GEARED LATHE

by which it was determined that the omission of speed 60 in the previous problem would reduce the efficiency proportional to the area *abcd*.

29 An analysis of this sort will show two things: first, that increasing the number of speeds without regard to the torque does not necessarily increase its adaptability to economic performance; second, that the amount by which the efficiency can be increased does not increase in direct proportion to the additional amount of speed changes provided,

TABLE 12 (FIG. 15) 24-IN. DOUBLE BACK-GEARED LATHE

CONE DIAMETERS 10½ IN., 12¾ IN., 15 IN; BELT WIDTH 4¼ IN.; COUNTERSHAFT SPEED = 300 R.P.M. FIRST BACK-GEAR RATIO 3.1 TO 1; SECOND BACK-GEAR RATIO 11.1 TO 1

Spindle Speeds r.p.m.	Torques ft.lb.
19	1476
27	1254
39	1032
68	410
98	350
139	288
210	133
300	113
429	93

Ng = 380 r.p.m.; Nl = 9.9 r.p.m.; maximum torque = 4608 ft. lb.

TABLE 13 (FIG. 16) 26-IN. "MASSIVE" LATHE

CONE DIAMETERS 7 IN., 9¾ IN., 12½ IN., 15¼ IN., 18 IN.; BELT WIDTH 4 IN.; COUNTERSHAFT SPEEDS 125 R.P.M.; BACK-GEAR RATIO 12 TO 1

Spindle Speeds r.p.m.	Torques ft.lb.
4.05	1800
6.65	1512
10.40	1250
16.3	975
26.8	700
48.6	150
80.0	126
125 0	104
196.0	81¼
322.0	58½

Ng = 277 r.p.m.; Nl = 8.15 r.p.m.; maximum torque = 5860 ft. lb.

even if the accompanying torques are properly determined. If 24 speed-torque combinations were properly spaced in the design represented in Fig. 14, the increase in efficiency over the eight already presented would not be twice as much as if 16 speed-torque combinations should be introduced in the same manner.

30 Closely associated with the matter of the increase in efficiency by the introduction of additional speed-torque changes is the problem of whether or not the increase is warranted by the increase in cost due to the additional equipment, and whether the management of the shop is such as to insure proper use of the additional equipment. The latter is in general the more vital question. In fact, the whole matter

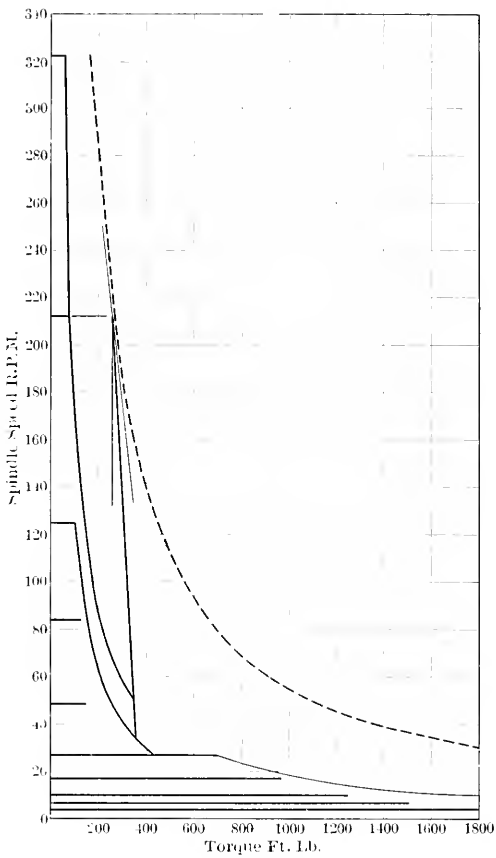

FIG. 16 26-IN. "MASSIVE" LATHE

of the efficiency of any machine as a part of a plant is as largely dependent on the management as upon the design of the machine.

31 But confining our attention particularly to questions of design, we note another field of usefulness for this method of analysis. It affords a means for determining the beneficial effects of motor equipment

on the efficiency of the machine. Given any particular machine with certain possible speed-torque combinations, what changes can be wrought by the use of direct motor drive when the motor has certain characteristics of speeds and torques? The limits of this paper will not permit a full discussion of this question, but it is pointed out as one way of determining the effect of motor drive on efficiency which will lead to more definite conclusions than any number of photographs illustrating the neater appearance of a motor-equipped machine over a belt-driven machine.

32 In conclusion it may be remarked that there seems to be need for a more rational method of procedure in determining the speed-torque characteristics of a lathe. While it is impossible to formulate all the conditions which a lathe may encounter in its operation, at the same time it is believed that a method of analysis such as that described in this paper will materially assist the designer in determining the speed-torque relations which are justifiable, and will enable the purchaser to determine whether or not the speed-torque characteristics of any given lathe are adaptable to his conditions.

FINISHING STAY-BOLTS AND STRAIGHT AND TAPER BOLTS FOR LOCOMOTIVES

By C. K. Lassiter,[1] Richmond, Va.

Non-Member

The locomotive boiler of average size contains about 1500 stay-bolts, the number varying from 1200 in the smaller sizes to 2000 or more in the heavier types. They vary in length from $4\frac{1}{2}$ in. to $10\frac{1}{2}$ in. for the water-space bolts, which constitute about 75 per cent of the total number, to about 28 in. for the radial and crown bolts.

2 Probably no part of the boiler is subject to more destructive conditions than these little staybolts. The most serious strains are those due to expansion and contraction of the inner sheet, which bend the bolts and cause them to break close to the outer sheet. This is especially true of the side or water-space stays, which are comparatively short and have very little flexibility.

3 The material used is a high grade of refined iron, close-grained and tough. The pitch being very important on account of entering the second sheet, these stays were formerly cut to length from the bar, drilled for centers, and threaded on engine lathes. The center-drilling was not always concentric and considerable time was required to center the rough bolt so that a good thread could be obtained. This method proving too expensive, bolt cutters were used for the work, but the results were not entirely satisfactory. It was difficult to cut the threads full and smooth with one passage of the chasers and the second passage was taken at the sacrifice of pitch, as well as of time, because there was not enough material to remove to carry the chasers along properly. The introduction of the lead screw in bolt cutters brought about a very considerable improvement in pitch, but still there was trouble in getting the thread smooth for the reason

The American Society of Mechanical Engineers, 29 West 39th Street, New York, June, 1910. All papers are subject to revision.

[1] Mechanical Superintendent, American Locomotive Company.

that the chasers were not always as accurate as the lead screw, under which conditions the threads would be rough or torn.

4 About thirty years ago the idea was conceived of concaving the bolts or reducing them in the center below the root of the thread, the object being to provide flexibility to compensate for the expansion between the inner and the outer sheets. Laboratory tests showed that a bolt reduced in the center would withstand about twice as many vibrations before breaking as one on which the threads were left straight for the full length. For many years it was the accepted practice to reduce a bolt in diameter on engine lathes after it was threaded in the bolt cutter and drilled for centers.

5 In 1900, Alonzo Epright, an engineer in the employ of the Pennsylvania Railroad, designed machines which were fully auto-

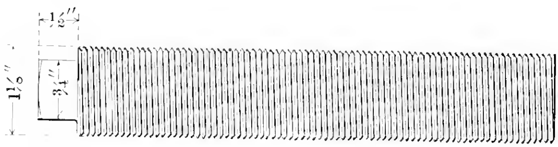

Fig. 1 Square End Water Space Stay (Plain,

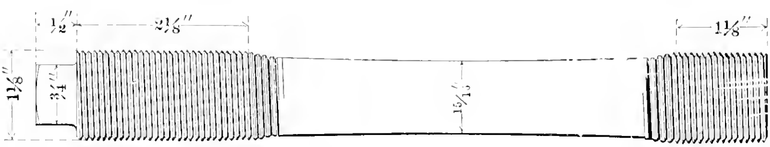

Fig. 2 Square End Water Space Stay (Concave)

matic in that they made from the bar, threaded and concaved, all diameters of side stays up to ten or eleven inches in length. The author has no knowledge of the production of these machines and therefore can make no comparison of costs.

6 The vertical type of machine for threading these bolts was used to some extent and it seemed that if the proper chaser could be made the best results would be obtained from this type of machine because the weight of the head would assist the chaser to give an accurate pitch. In the horizontal or bolt cutter type the chaser must carry along the vise and carriage to the detriment of accuracy in the lead. Also, the flow of oil would assist in washing away the chips, which were troublesome in the horizontal machine. Furthermore,

the vertical type of machine is more convenient to operate, one man attending six or eight spindles with ease.

7 After a great deal of experimenting a die head was developed in which, with chasers properly ground, the limit of accuracy of 0.01 in. in 8 in. can be maintained without the use of the lead screw, which is more nearly a perfect pitch than many staybolt taps in daily use. Where a proper lubricant is used a very fine, smooth thread can be obtained at a uniform cutting speed of 20 ft. per min.

8 The turning or reducing tools are shown in Fig. 3, the cutting points being visible at the center, back of the chasers. To these tools

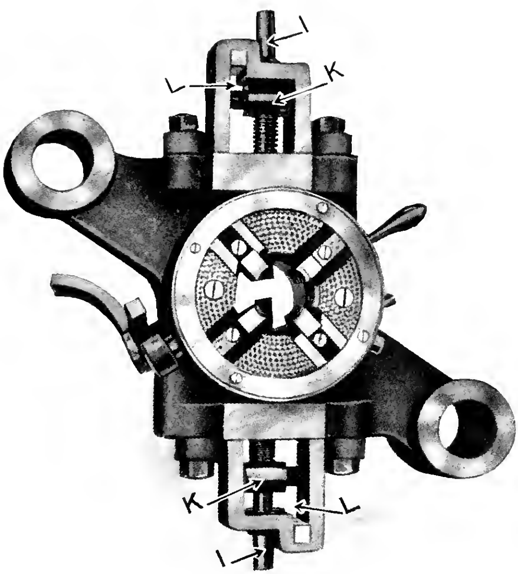

Fig. 3 Die Head for Threading Staybolts

are attached the crossheads *KK*, which are actuated by profilers or formers passing through the spaces *LL*, over which the head is drawn by the chaser, the staybolt acting as a lead screw.

9 The staybolt-threading machine is shown in Fig. 4. The several die heads are attached by small rods to straps passing over the pulleys on a shaft at the top of the machine. The operator grasps one of the strap handles with his right hand and, by the aid of the rotating

pulley over which the strap passes, raises the die head until it comes in contact with the bracket which closes the die. With his left hand he places the squared end of a staybolt in a holder underneath the die and allows the head to drop until the chasers begin to cut, when he moves to the next die head and repeats the operation. By the time he has placed all the heads in operation, the first bolt is finished, the die having dropped automatically when the threading was completed.

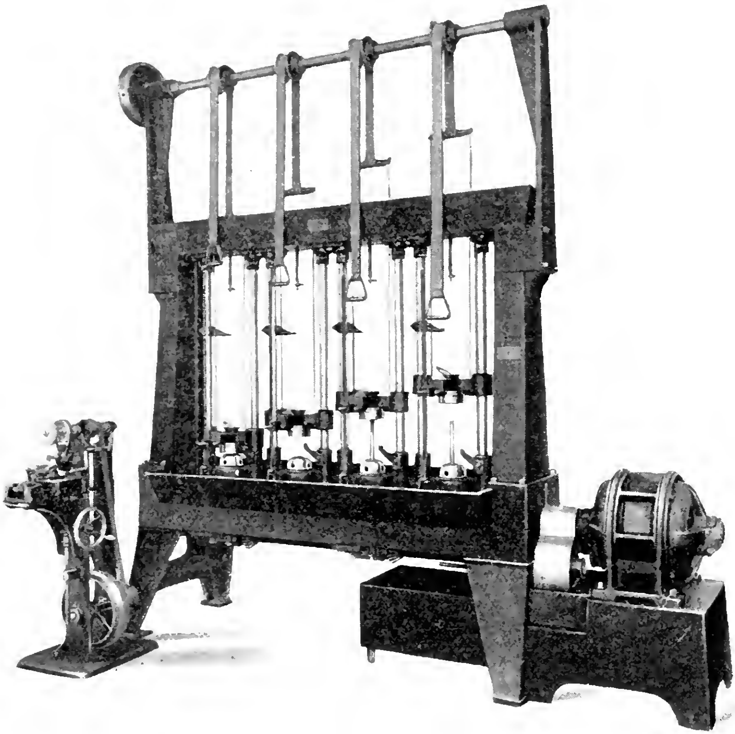

Fig. 4 Staybolt-Threading and Reducing Machine, with Special Grinder for Cutting Tools

10 In Fig. 4, the die head at the right is shown raised sufficiently to insert the staybolt in place; the next at the left is just beginning to thread the bolt and the two other die heads are in still lower positions.

11 A comparison of costs by the two methods, taking a $7\frac{1}{2}$-in. side stay as an average length, would be about as follows:

FORMER PRACTICE

Threading-in bolt cutter, usually taking two cuts at 20 cents	$0.40
Drilling for centers	0.22
Concaving or reducing on engine lathe	0.75
Cost per hundred	$1.37

PRESENT PRACTICE

Present cost, threaded the entire length or threaded and concaved for all sizes and lengths, per hundred	$0.13

Using the average number of stays, a saving of labor cost of $18.60 per boiler is obtained with a minimum of rejected stays.

METHODS OF DRILLING STAYBOLTS

12 The telltale holes which are drilled in the staybolts have been the cause of considerable expense and annoyance. Some railroads drill them after the stays are placed in the boiler, with pneumatic hand drills. Under these conditions there is danger that the hole may not be central. It often happens that the drill runs through into the water space or is broken off in the hole. In either case it is necessary to remove the bolts and put in others. Sometimes the holes are drilled on a vertical drilling machine before being placed in the boiler. Even then the breakage of drills is very large, averaging about sixteen to the boiler, and each broken drill means a staybolt thrown away.

13 An automatic machine has been devised for drilling these holes before the stay is placed in the boiler. They are fed from a hopper and automatically centered in position for the drill. When the hole is bored about one-third of the depth, the drill is withdrawn and the bolt is carried forward in the turret mechanism which holds it to a second and a third drill, completing the hole. Each drill is 0.01 in. smaller than the preceding one, providing for a minimum of friction and a maximum of clearance for chips. The holes are of uniform depth and in the center of the bolt. The average breakage is about three or four drills to the boiler.

COMPARISON OF COSTS

Drilling in the boiler, per hundred (to which should be added the cost of replacements	$0.90
Drilling under drill press, per hundred (to which should be added cost of drills and waste of material and labor)	0.45
Drilling in the automatic machine, per hundred (with the minimum number of broken drills and bolts destroyed)	0.12

METHODS OF FINISHING STRAIGHT AND TAPERED BOLTS

14 The usual method of finishing straight and tapered bolts for locomotives was to drill for centers, place in engine lathes, face under the head, turn the body taper, turn the part to be threaded straight and to proper size, face down the thread end to length and shape, leaving the center intact, test and file to accuracy, and cut off center point, after which the bolt is ready to be threaded in the bolt cutter and to have the hexagon head changed to any special shape desired.

15 About 1889, S. M. Vauclain, Mem.Am.Soc.M.E., designed and used a turning head in connection with a vertical machine for bolts up to 12 in. long. Under rights obtained from him the Pennsylvania Railroad placed an equipment of this kind in its Altoona shops and that is the only railroad known to the author using other than engine lathe methods in finishing bolts.

16 As a great many straight and tapered bolts used in locomotives are 12 in. to 20 in. in length and even longer, it became necessary to design for this work a turning head which would handle taper bolts up to 18 or 20 in. in length and up to $1\frac{3}{4}$ in. diameter of thread, and straight bolts in any length up to 27 in. and up to $2\frac{1}{2}$ in. diameter. It may be quite possible to go beyond these dimensions should the specifications require. These requirements have been met by a special machine of the vertical, multiple-spindle drill type, with which is used a special cutter head shown in Fig. 5. This head is the real or essential means of producing these bolts, either straight or taper and cylindrically true to the axis, the machine being simply a proper means of driving and feeding the bolt during the turning operation.

17 The cutter head consists of a retaining shell of cast iron, the bore of which must be round and straight; six segments, three of which are rigidly fastened to the shell, the other three having a limited amount of freedom and being fastened in place by a taper key with an adjusting screw located in the center of the radius with a bearing on the shell; and three blades, alternating with three guides, placed between the segments and backed up with taper keys and adjusting screws. The taper keys, in connection with a certain amount of taper on the blades and guides, have sufficient movement to provide for about one-eighth inch adjustment for re-grinding of the blades, or with the same amount on the guides, one-quarter inch in diameter of bolts. It will readily be seen that when an accurately ground plug gage of the size that it is desired to turn the bolt is placed centrally in the head, the blades and guides can be adjusted to their proper position. The three

loose segments are then forced forward by the taper key, clamping the blades and guides rigidly in their proper working position.

18 The economical use of this method of turning bolts, particularly in the railroad shops and locomotive works where taper bolts are largely used, necessitates a change of system. The usual practice, especially on repair work, has been to carry in stock only standard sizes of forgings, though in some cases the more common sizes were placed in stock finished. With the engine lathe located near the locomotive being repaired, the bolts were fitted to the hole after the least possible amount of reaming had been done that would clean up the hole.

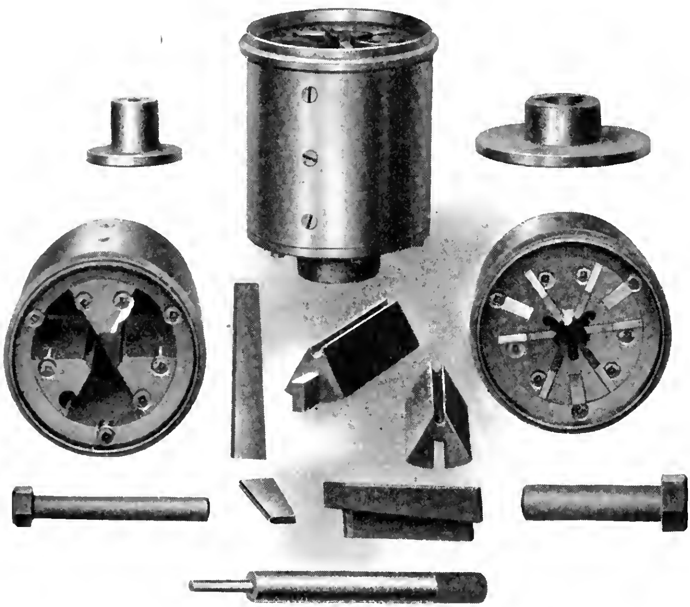

Fig. 5 Cutter Head and Attachments

19 The improved system contemplates the turning, facing under the head, and placing in stock of standard sizes in lengths of 6, 9, 12, 15, and 18 in. and varying in diameter under the head by thirty-seconds of an inch. Stock may be kept in sixty-fourths of an inch if desired, but very few holes will be found which require less than thirty-

seconds of an inch to clean up. In fact, the chief reason for carrying the intermediate sizes would be to save the hole when it cannot be cleaned up within the next thirty-second. Standard reamers are used, with collars or marks to indicate when they have been driven to the required depth. All bolts have standard hexagon heads conforming to the thread diameter.

20 Bolts are specified with relation to the length and the diameter under the head, and the stock size next longest is used. Under these conditions not more than 3 in. must be cut off to bring the bolt to the proper length. The stock bolts are then taken to the bolt-altering machine, which is a quick-acting hand machine equipped with collet chucks and split bushings for the various diameters of the bolts. The end may be cut off to the proper length and turned for cotter pins, and the head changed to counter sink, box head, button head, or whatever may be required. After threading on the bolt cutter, the bolt is ready to drive in place without further fitting.

21 A comparison of costs by the two methods, taking a $1\frac{1}{8}$ in. × 9 in. bolt as an average would be about as follows:

ENGINE LATHE PRACTICE

	Cost per hundred
Drilling for centers	$0.22
Turning in lathe	2.50
Altering in lathe	$2.50 to 3.50
Threading in bolt cutter	0.22
Cutting off center points	0.10

PRESENT PRACTICE

Pointing the blank	$0.12
Turning by the method described	0.45
Cutting off and changing points and heads where necessary on the bolt-altering machine	$0.40 to 0.60
Threading in the bolt cutter	0.22

22 A device is now being perfected by which the threading can be done automatically at the same time the turning is done. This not only eliminates the bolt cutter charge of $0.22 per hundred, but assured a full, uniform thread absolutely in line with the body of the bolt and square with the facing under the head. When used in connection with a nut faced square with its thread the most satisfactory bolt is obtained.

23 A combined turning and threading device implies a modified form of the cutter head previously described, underneath which is

TABLE OF STOCK SIZES

Showing Eight Threaded Diameters of Bolts and Thirty-Two Diameters Under the Head

Thread Diameter	$\frac{3}{4}$				$\frac{7}{8}$				1				$1\frac{1}{8}$			
Diameters under head	$\frac{25}{32}$	$\frac{13}{16}$	$\frac{27}{32}$	$\frac{7}{8}$	$\frac{29}{32}$	$\frac{15}{16}$	$\frac{31}{32}$	1	$1\frac{1}{32}$	$1\frac{1}{16}$	$1\frac{3}{32}$	$1\frac{1}{8}$	$1\frac{5}{32}$	$1\frac{3}{16}$	$1\frac{7}{32}$	$1\frac{1}{4}$
Length under head......	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
					9	9	9	9	9	9	9	9	9	9	9	9
										12	12	12	12	12	12	12
													15	15	15	15
															18	18

Thread diameter	$1\frac{1}{4}$				$1\frac{3}{8}$				$1\frac{1}{2}$				$1\frac{5}{8}$			
Diameter under head	$1\frac{9}{32}$	$1\frac{5}{16}$	$1\frac{11}{32}$	$1\frac{3}{8}$	$1\frac{13}{32}$	$1\frac{7}{16}$	$1\frac{15}{32}$	$1\frac{1}{2}$	$1\frac{17}{32}$	$1\frac{9}{16}$	$1\frac{19}{32}$	$1\frac{5}{8}$	$1\frac{21}{32}$	$1\frac{11}{16}$	$1\frac{23}{32}$	$1\frac{3}{4}$
Length under head......	6	6	6	6	6	6	6	6								
	9	9	9	9	9	9	9	9								
	12	12	12	12	12	12	12	12	12	12	12	12				
	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18

attached a die head of special construction. This die head is carried on four or more vertical rods or guides which are attached to a ring to which the cutter head is fastened. Provision is made for squaring the die head with the cutter head at the time it begins cutting the thread, and at the same time automatically placing the die head in a position where it is free to move in a vertical plane up or down in exact proportion to the difference between the feed and the pitch of the thread to be cut. An automatic knock-out is provided which opens the die head and passes to one side, allowing the threaded bolt to go through to any length within the feed of the machine. Under these conditions it will be seen that so long as the length of the thread to be cut is the same, the length of bolt to be turned is immaterial. The device is very simple in its construction and does not call for a skilled mechanic to adjust or operate it.

TWO PROPOSED UNITS OF POWER

By Prof. Wm. T. Magruder, Columbus, O.

Member of the Society

James Watt is said to have defined a "horsepower" as 33,000 foot-pounds of work per minute, and a "boiler horsepower" as the evaporation of a cubic foot (62 lb.) of water per hour. His rule is sometimes put into the form that "one square foot of grate surface, one square yard of heating surface, a half of a square yard of water surface, and one cubic yard of contents, equals one horsepower, and will evaporate one cubic foot of water per hour in a waggon boiler."

2 Charles E. Emery, Charles T. Porter and Joseph Belknap, "Committee on Boiler Trials of the Judges of Group XX," reported through Horatio Allen, Chairman of Group XX, to Prof. Francis A. Walker, Chief of Bureau of Awards of the United States Centennial Commission of the International Exhibition of 1876, that "the estimated Horse-Power of the several boilers" was given "on the basis that the evaporation of thirty pounds of water is required per horsepower per hour, the results being derived from evaporation at steam pressure of 70 pounds from temperature of 100°."[1] In the Report of the Committee of Judges of Group 20, p. 131, as published by J. B. Lippincott & Co., Philadelphia, "the commercial horse-power of a boiler is fixed at 30 pounds of water evaporated at 70 pounds gage pressure from a temperature of 100 deg."[2] It is to be noted that the time element is omitted. This is not an unusual mistake in speaking of rates, the time element being understood, or taken for granted. This definition is commonly modified so that the Centennial standard of horsepower or the "Centennial horsepower" is defined as the

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[1] United States International Exhibition, 1876. Reports and Awards, vol. 6, p. 426, sect. 35.

[2] Trans. Am. Soc. M. E., vol. 21, p. 84. Report of Committee on Revision of Standard Code.

"evaporation of thirty pounds per hour of water at 100 deg. fahrenheit into dry steam at 70 pounds gage pressure, or the equivalent." This last phrase is very generally omitted. It is interesting to note that the committee called it the "commercial horsepower," and not a "boiler horsepower." They also defined the "unit of evaporation" as one pound of water at 212 deg. fahr. evaporated into steam of the same temperature, and as being equivalent to 965.7 heat units.

3 In the Appendix is given a summary of the reports of committees of the Society relating to horsepower units and of various discussions on the subject. From these it will be seen that while trying to keep to the Centennial standard of commercial (boiler) horsepower, the committees have gradually veered to the thermal-unit standard, and from the standard of 30-lb. from 100 deg. fahr., into steam at 70-lb. gage pressure.

4 Since 1876, the accuracy of our knowledge of the heat of steam has increased. This is especially true since 1899, the time of the last report to the Society. The "confusion to practical boiler owners," which Dr. Chas. E. Emery seemed[3] to fear might result from the practice of measuring the power of a steam boiler in heat units, does not seem to have materialized.

5 The publication of the new eighth edition of Professor Peabody's Tables of the Properties of Steam, and the publication of the Tables and Diagrams of the Thermal Properties of Saturated and Superheated Steam by Professors Marks and Davis, have complicated this matter still more, and especially with engineering students.

6 According to the steam tables of Charles T. Porter, and the various reports that have been referred to on this subject, the value of the "unit of evaporation" is 965.7 B.t.u. According to Peabody, its value has been gradually changing to 965.8, 966.3, and now to 969.7. According to Marks and Davis, its value should be 970.4. These differences amount to only 4.7 B.t.u. in 970.4, or to one in 205, which is one-half of one per cent. It would seem desirable to use 970 hereafter, instead of 966, as the unit of evaporation, this being the average of the most accurate determinations of the latent heat of evaporation of water at 212 deg. fahr.

7 Similarly, the "unit of commercial evaporation" has been changing from 1110.2 B.t.u. in 1876 and 1884, to 1115.0 according to Peabody, and to 1115.6 B.t.u. according to Marks and Davis today.

[3] Trans. Am. Soc. M. E., vol. 6, p. 334. Report of Committee on Revision of Standard Code.

8 When measured in thermal units, the value of the boiler horsepower, 34½ units of evaporation, is given as 33,305 B.t.u. by the Centennial judges and by the committee reporting to the Society in 1884; as 33,317 B.t.u. in the report of the committee as made in 1899; as 33,320 B.t.u. in one text book on steam-boilers; as 33,454.7 B.t.u. (34½ x 969.7) by Peabody; and as 33,478.8 B.t.u. (34½ x 970.4) by Marks and Davis.

TABLE 1 DIFFERENT VALUES OF A BOILER HORSEPOWER IN B. T. U.

	Units of Evaporation		Units of Commercial Evaporation		B. T. U.
	One	34½	One	30	
Centennial	965.7	33,317	1110.2	33,306	33,305
Peabody	969.7	33,455	1115.0	33,450	....
Marks and Davis	970.4	33,479	1115.6	33,468	....

9 It must be evident to everyone that a would-be standard which has so many different thermal values and is capable of acquiring others with each change in the steam tables is not only indefinite but confusing. It is not a definite unit of measurement, which all standards should be. It seems a pity that in the definition of such a commonly used engineering term there should be any possible chance for confusion and misunderstanding on the part of the student, or for litigation between contractors over the accuracy of the fulfillment of the terms of the contract.

10 Again, for over thirty years, engineers and engineering teachers have been apologizing for the use of the term "boiler horsepower." Even the committee of the Society which reported in 1884, says,[4] "It cannot properly be said that we have any natural unit of power for rating steam boilers." If a horsepower is the rate of doing work, and a boiler is considered as a machine, and the water as the moving parts, the only mechanical power that a boiler produces is that due to the external latent heat of evaporation, except when it explodes. Hence the term "boiler horsepower" is a misnomer. The object of the use of a boiler is the absorption of the heat energy obtained from the potential energy of the fuel by combustion, and the transfer to and

[4] Trans. Am. Soc. M. E., vol. 6, p. 263. Report of Committee on Revision of Standard Code.

storage of the same by a volatile liquid for convenient use in a heat engine, or for other thermal purposes. Hence as a boiler uses the latent heat energy of the fuel as its source of supply, and develops and delivers available heat energy, there would seem to be every reason why the power or ability of a boiler to deliver energy should be measured in thermal units, as being the only unit of energy that the boiler ever normally receives or delivers. Furthermore, the energy from every boiler is always measured in heat units before being reduced to boiler horsepower.

11 To measure the capacity or power of a boiler plant, or its output of energy, in millions of thermal units would not be practical; a smaller unit is desirable. It is therefore proposed to measure the power or capacity of a boiler in "boiler-powers," and to define a boiler-power as 33,000 B.t.u. of heat energy delivered per hour by a steam-boiler, steam main, or by a hot-water heating main, or the like, or added per hour to the feed-water of a boiler, or to the water of a hot water heating system. The acceptance of this term will, it is thought, simplify the whole subject; the unit will remain constant, will be easily remembered and easily used, and will not be one of three standards, differing slightly among themselves, as is at present the case with the term boiler horsepower. Its analogy to mechanical horsepower will be helpful rather than the opposite, especially to the beginner in engineering knowledge. The unit boiler horsepower may still be retained by those who may prefer to use it in some one of its many thermal values.

12 The rapid introduction of gas engines using blast furnace, coke oven, or producer gas, leads to the suggestion of a new unit for the capacity or power of a gas producer, coke oven, or blast furnace, to deliver available heat energy for use in gas engines, under stoves and boilers, or for other thermal uses.

13 At the St. Louis meeting of the American Association for the Advancement of Science in December 1903, the writer read a paper suggesting the term "producer horsepower" as a unit. Since then the question has arisen as to why the old misnomer of "horsepower" should be perpetuated as a unit of measurement of heat energy. Why not simplify and shorten the term "producer horsepower" to "producer power?" If such a unit is desirable for the measurement of the capacity or power of a gas producer, why not suggest similar ones for other generators of heat energy available for use in gas engines and for other thermal uses? Instead of measuring the power of a gas producer in producer powers, and the powers of a blast furnace and

of a coke oven to generate heat energy in blast-furnace powers and coke-oven powers, it is proposed to include all such sources of power, and to measure the heat energies of gaseous and liquid fuels, in "gas powers," and to define a gas-power to be 10,000 B.t.u. of heat energy delivered per hour by a gaseous or liquid fuel. The calorific value should be measured from and to 62 deg. fahr., and at 30 in. of mercury. This unit can be applied and used in the measurement of the energy delivered by a gas well, a gas main, a gas producer, a blast furnace, a coke oven, an oil well, or a pipe line.

14 The number, 10,000 B.t.u., has been chosen as the average in the best gas-engine practice today of heat energy required to develop a horsepower of mechanical energy. The figure bears to current gas-engine practice about the same relation that 30 lb. per hr. of steam at 70 lb. gage pressure from water at 100 deg. fahr. did to current steam-engine practice in 1876. The definition as given contemplates using only the higher calorific value of the fuel, rather than the lower or, so-called, effective value.

15 It is to be hoped that some such unit for the measurement of the output of a generator of heat energy in gaseous or liquid form can be found, and adopted by common consent, before practice and commercial custom in different portions of the country shall have learned to use units which have been less carefully selected and less accurately defined.

APPENDIX

In a paper presented before the Society by Wm. Kent,[1] at the Pittsburg Meeting in May 1884, he tabulates the "horsepower developed at 30 lb. of water evaporated per hour from and at 212°. (Page 268)." In a footnote we read, "The customary method of rating horsepower is 30 lb. of water per horsepower per hour from a feedwater temperature of 212° into steam at 70 lbs. pressure above the atmosphere, which is equal to 30.985 lbs. from feed at 212° into steam of the same temperature. The writer prefers the calculations both of economy and horsepower to be made on the basis of evaporation from and at 212°, for the sake both of uniformity and of convenience in calculation."

2 In a paper presented before the Society by Dr. Chas. E. Emery at the same meeting,[2] he defines the Centennial horsepower (C.H.P.), as being "thirty Kals per hour;" and a "Kal" as being "one pound of water evaporated into saturated steam at seventy pounds pressure from temp. of 100°, with a thermal value of 1110.2 thermal units (Page 282)." This would make a Centennial horsepower equivalent to 33,306 B.t.u. In discussing this paper, Mr. Kent argued that "in determining the horsepower in a steam boiler . . . we should start with the British thermal unit as a basis . . . The unit of evaporation should be 965.7 thermal units. It is the evaporation of one pound of water from and at 212 degrees. A horsepower should be a definite number of units of evaporation—say 30 (Page 297)." He was followed by Dr. E. D. Leavitt, Jr., who thought that "the simplest proposition was to come down to thermal units." Dr. Emery assented that any unit proposed must be based on the "heat unit." In the Centennial Report, this amount of heat energy (1110.2 B.t.u.) was termed the "unit of commercial evaporation (Page 300)."

3 In the Report of the Committee on a Standard Method of Steam-Boiler Trials made at the New York Meeting of the Society in November 1884,[3] the Centennial unit of boiler-power is stated as "30 pounds of water evaporated into dry steam per hour from feed-water at 100° Fahrenheit, and under a pressure of seventy pounds per square inch above the atmosphere." "The quantity of heat demanded to evaporate a pound of water under these conditions is 1110.2 British thermal units, or 1.1496 units of evaporation. The unit of power proposed is thus equivalent to 33,305 heat-units per hour, or 34.488 units of evaporation." Another standard unit for the power of a boiler which was suggested to the Committee in 1884 was "the evaporation of thirty pounds of feed-water into dry steam from and at the boiling point at mean atmospheric pressure (212°F.) (Page 265)." This would have then been taken as the equivalent of 30 x 965.7 = 28,971 B.t.u. per hr. It was not accepted.

[1] Trans. Am. Soc. M. E., vol. 5, p. 260. Rules for Conducting Boiler Tests.
[2] Trans. Am. Soc. M. E., vol. 5, p. 282. Estimates for Steam Users.

4 This Committee recommended in 1884 the adoption of the Centennial Standard and that, for standard trials of steam boilers, the "commercial horsepower be taken as an evaporation of 30 pounds of water per hour from a feed-water temperature of 100° Fahr. into steam at 70 pounds gauge pressure, which shall be considered to be equal to $34\frac{1}{2}$ units of evaporation; that is, to $34\frac{1}{2}$ pounds of water evaporated from a feed-water temperature of 212° Fahr. into steam at the same temperature. This standard is equal to 33,305 thermal units per hour (Page 266)." A footnote gives the "evaporation of $34\frac{1}{2}$ pounds from and at 212°F., as being equal to 30.010 pounds from 100°F., into steam at 70 pounds pressure," and "the 'unit of evaporation' as being 965.7 thermal units," according to the tables in Porter's Treatise on the Richards Steam Engine Indicator, which was the standard of that day.

5 Dr. Chas. E. Emery stated[3] that the "commercial horsepower of $34\frac{1}{2}$ units of evaporation per hour is, for all practical purposes, equal to 33,333 thermal units per hour making it convenient to obtain the horsepower by multiplying the total number of thermal units derived from the fuel per hour by 0.00003 (Page 304)."

6 Prof. J. B. Webb in speaking about the definition of a "commercial horsepower" said "To my mind it would be simpler and better to express results in *thermal units per hour*, and at all events not to express them in horsepowers which are very far from being horsepowers (Page 322)." Nothing came of his suggestion.

7 During this discussion, Wm. Kent introduced and used the term "boiler horsepower" rather than "commercial horsepower," and quoting the definitions of commercial horsepower as recommended by the committee, added, "This standard is certainly not open to the charge of want of exactness and precision (Page 324)."

8 The Committee in its report said that it had "concluded to recommend thirty pounds as the unit of boiler-power (Page 264)".

9 Dr. Charles E. Emery stated that "it was informally suggested to make the standard exactly 33,000 British Thermal Units per hour, so that it would be numerically the same as the number of foot-pounds per minute constituting an actual horsepower, and again 33,333 B.t.u. were suggested to facilitate the calculations, but the general feeling of the committee was against any change whatever (Page 333)." He adds, and seems to prefer the statement that "The value of the unit of horsepower announced is 33,305 British Thermal Units per hour, which being stated in the Report definitely fixes the standard. It also equals $34\frac{1}{2}$ units of evaporation, within one-thirtieth of one per cent."

10 Prof. W. P. Trowbridge, in discussing the report, called attention to the diversity of opinion in the committee as to whether the "unit of boiler-power" should be expressed in terms of the "unit of evaporation," or in some other terms.

11 Prof. W. P. Trowbridge and Prof. C. B. Richards presented a paper at the Boston meeting in 1885 on The Rating of Steam Boilers by Horse-Powers for Commercial Purposes,[4] in which they differ from the committee which had reported the preceding year, but quote its report with the statement "What is

[3] Trans. Am. Soc. M. E., vol. 6, p. 256.
[4] Trans. Am. Soc. M. E., vol. 7, p. 214.

needed is a standard unit of boiler power which may be used commercially in rating boilers, and in specifications presenting the power to be demanded by the purchaser and guaranteed by the vender (Page 216)."

12 George H. Babcock in discussing this subject said, "A dynamic horsepower in its simplest form is 33,000 foot-pounds per minute. A boiler horsepower should be defined as 33,000 heat units per hour imparted to the water (Page 225)." Mr. Kent stated, "The term horsepower has two meanings in engineering literature: First, an absolute unit or measure of the rate of work, ... and an approximate measure of the size, capacity, value, or "rating," of a boiler engine, water-wheel or other source or conveyor of energy, by which measure it may be described, bought and sold, etc. (Page 226)."

13 In the Report of the Committee on the Revision of the Standard Code for Conducting Steam-Boiler Trials, made in 1899,[5] it is stated (Page 36) that "The Committee approves the conclusions of the 1885 Code to the effect that the standard 'unit of evaporation' should be one pound of water at 212 degrees Fahr. evaporated into dry steam of the same temperature. This unit is equivalent to 965.7 British thermal units. The Committee recommends that, as far as possible, the capacity of a boiler be expressed in terms of the 'number of pounds of water evaporated per hour from and at 212 degrees.' It does not seem expedient, however, to abandon the widely recognized measure of capacity of stationary or land boilers expressed in terms of 'boiler horsepower.' The present committee accepts the same standard, but reverses the order of the two clauses in the statement, and slightly modifies them to read as follows: 'The unit of commercial horsepower developed by a boiler shall be taken as $34\frac{1}{2}$ units of evaporation per hour; that is, $34\frac{1}{2}$ pounds of water evaporated per hour from a feed-water temperature of 212 degrees Fahr. into dry steam of the same temperature. This standard is equivalent to 33,317 British thermal units per hour. It is also practically equivalent to an evaporation of 30 pounds of water from a feed-water temperature of 100 degrees Fahr. into steam at 70 pounds gauge pressure.'" In a footnote is added the statement that "The unit of evaporation being equivalent to 965.7 thermal units, the commercial horsepower = 34.5 x 965.7 = 33,317 thermal units (Page 37)."

[5] Trans. Am. Soc. M. E., vol. 21, p. 34.

GAS ENGINES FOR DRIVING ALTERNATING-CURRENT GENERATORS

H. G. Reist, Schenectady, N. Y.

Member of the Society

The problem of driving an alternating-current generator by means of a gas engine is not inherently different from that of driving it from a steam engine. If the shaft of the engine turned with a uniform motion, no difficulty would be experienced and no special design would be necessary. It is the variations in angular velocity and speed that affect the driving of alternators.

2 If the current of a single generator is used for lights or for heating, as in electric furnaces or in electrolytic work, variations in velocity either during a single turn or due to the hunting of the governor will simply increase and decrease the load as the speed varies. If induction motors are driven from a single generator, it is only under peculiar circumstances that any trouble is experienced due to speed variations in the engine, because this type of motor is asynchronous and does not have to follow exactly; it is as if it were belted to the engine, the connection being slightly flexible.

3 A synchronous motor or rotary converter, on the other hand, must keep in phase and behave as though geared to the engine, and must respond to all its speed variations. If it does not keep absolutely even, that is, if its phase relations change, cross currents will flow. When two or more generators are operated in parallel, their behavior is similar, any angular departure of one from the other causing a cross-current. The volume of the cross-current depends, with any given design of generator, on the angular departure of the generators from each other. This departure may be twice the angular variation of the engine rotating parts from a mean position, because one may be a maximum distance ahead while the other is in the most backward position.

The American Society of Mechanical Engineers, 29 West 39th Street, New York, June 1910. All papers are subject to revision.

4 If the generators were mounted on the shaft so that the relations of the poles to the cranks were identical, and if it were possible so to synchronize them that the corresponding cranks of engines to be run together were exactly together, no cross-currents would flow, because the engines would slow down and speed up together. This is not feasible, however, and it becomes necessary to design the engine to run with a fairly uniform rotation. It has been found good practice to limit the variation from a mean position of the revolving parts of the electric generator to $1\frac{1}{4}$ electrical degrees.

5 An electrical degree is 1-360 part of the space occupied by two poles on a generator; that is, a two-pole generator is the unit and an electrical degree is one mechanical degree of such a machine; if the generator has four-poles, an electrical degree will be one-half a mechanical degree of the circle on which the poles are mounted; if there are 6 poles, it will be one-third of a mechanical degree. In general, to reduce electrical degrees to mechanical degrees, we must divide the allowable variation by one-half the total number of poles on the generator; so that the $1\frac{1}{4}$ electrical degrees mentioned above for a twenty-pole machine would be 0.125 actual degrees on the circumference of the flywheel. From this it is evident that with a generator of many poles, a more even speed is needed than for one with few poles. For a 60-cycle generator, which at a given engine speed has $\frac{60}{25}$ as many poles as a 25-cycle generator, the evenness of running must be much greater than for a 25-cycle generator.

6 The cross-currents between two electrical generators tend to speed up the lagging machine, bringing them more closely into synchronism. If there were no inertia the rotating parts of generator and flywheel would quickly get into synchronism, reducing and almost eliminating the cross-currents. This is, however, an ideal condition. The cross-currents are a factor of the amount of inertia with a given natural angular variation, and it will readily be seen that from this standpoint the larger the flywheel the less effect a given value of currents or torque will have on the mass. If the flywheel is very large, the currents which it may be practical to allow to flow between the machines may not be able to draw them together at all. Hence a large flywheel, while useful in obtaining uniform rotation, so far as the engine is concerned, prevents the current flowing between the machines from being very effective in drawing them into synchronism. This shows that it is desirable to obtain uniform rotation in other ways than by the use of an excessively heavy flywheel. Currents flowing between machines occasion losses in the copper and this

adds to the heating of the machine. They thus reduce the output with a given rise of temperature and reduce the efficiency.

7 Certain elements of design may be introduced into an electrical generator to make it less sensitive to slight variations in turning moment supplied by the engine, such as building a generator of poor regulation. The regulation must not be too poor, however; otherwise the operation of the system will be unsatisfactory. A "squirrel-cage" winding in the poles of the generator allows secondary currents to flow in this part of the structure and increase the torque, tending to draw the generators together with a given interchange of current between the two machines. This is of great assistance in parallel operation of generators and should generally be applied on generators to be driven by gas engines. If a flexible connection could be provided between engine and generator it would greatly assist in satisfactory parallel operation, but this connection is generally applicable only on small machines. The ultimate solution lies in the direction of greater uniformity of motion in the engine itself.

8 Uniformity of rotation of gas engines is dependent on a number of elements of design, such as (*a*) the number of impulses per revolution, which in turn is dependent on the number of cylinders and arrangement of cranks and on whether a two or a four-cycle system is used; (*b*) the compression and weight of the reciprocating parts; (*c*) the time of ignition; (*d*) the weight of the flywheel. The use of a heavy flywheel, however, while one of the simplest, is the least desirable method of obtaining even rotation of the engine shaft, and other means should be used to obtain as uniform rotation as possible.

9 The following seem to be the desirable characteristics of gas engines for driving alternators:

- *a* High speed. This will require fewer poles with a given frequency and a greater angular variation will be allowable.
- *b* A light flywheel. This will allow the current to keep the generators together with a minimum disturbance.
- *c* Large engines should be built with many cylinders and cranks so placed as to contribute to an even turning moment.

CRITICAL SPEED CALCULATION

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Non-Member

Critical speed is the term applied to the speed of a rotating body at which occur the maximum vibrations of the revolving mass or supporting structure. The vibrations are smaller for speeds both above and below the critical value. Hence the importance, to the designer of high rotative speed apparatus, of predetermining these maximum vibrating points. The high speeds and large capacities now being used in electrical machinery, such as turbo-generators, frequency changers, etc., bring this apparatus within the critical-speed range; and the electrical designer must study the vibrating properties of his high speed machines, or leave this operating trouble to chance.

2 The phenomenon of critical speed was known to De Laval, who designed his turbines with a small or "flexible" shaft, so that the running speed was seven to ten times the critical value. So far as is known he did not understand the mathematical theory.

3 The first scientific explanation of critical speed is due to Rankine who in Machinery and Millwork gave the mathematical explanation for a shaft with its own weight only, when supported at each end, and also for fixed direction at one end as a cantilever. This was followed by Professor Greenhill[2] with an explanation for an unloaded shaft with fixed direction at each end. Professor Reynolds[3] then extended the mathematical treatment to shafts loaded with pulleys, and Professor Dunkerley[3] proved the formulæ by laboratory experiments and developed an approximate formula for shafts with more than one load. Reynolds and Dunkerley do not satisfactorily treat

[1] General Electric Company, Schenectady, N. Y.

[2] Proceedings Institution of Mechanical Engineers, April 1883.

[3] Philosophical Transactions, Royal Society, London, vol. 185a, 1895; Proceedings, Liverpool Engineering Society, 1895.

The American Society of Mechanical Engineers, 29 West 39th Street, New York. All papers are subject to revision.

the case of two loads on the shaft and their method was criticised by Dr. Chree.

4 Föppl[1] in Germany gave the case for a single concentrated load of the shaft. Stodola[2] in 1903 first gave the formula for any two concentrated loads on a shaft. Professor Morley[3] has lately given approximate formulæ for combined distributed and concentrated loads.

5 These constitute practically all of the literature on the subject. They are mainly mathematical demonstrations and do not leave the subject in convenient form for the use of the designing engineer. This paper will give a mathematical treatment for both the distributed and the concentrated loads, by considering the motion of the shaft as vibratory along two axes, study the vibrations for all speeds, reduce the formulæ to practical form, and present them in tables for convenient use.

NATURE OF CRITICAL SPEED

6 To explain more easily the nature of critical speed we will first give the simple solution of Föppl for a single load. All critical-speed calculations assume an unbalanced load. It is practically impossible to balance a rotating mass so that its center of gravity exactly coincides with the mechanical axis of rotation. As the mass starts to rotate, the center of gravity will rotate in a very small radius around the shaft center. The rotation of the center of gravity at this small radius produces a centrifugal force which acts radially outward from the shaft center through the center of gravity, and rotates around the shaft with the center of gravity. Consider the case shown in Fig. 1, of a single concentrated load on a vertical shaft. Let a be the unknown distance from the center of gravity of the mass to the center of the shaft. The centrifugal force of this mass m, rotating at the radius a, will tend to deflect the shaft in the direction of a, so that the shaft will rotate in a bowed condition. The bowed shape will in itself increase the circle in which the center of gravity rotates; this increases the centrifugal force, and in turn the shaft deflection. This action continues until finally a state of equilibrium is reached where the force of the shaft deflection is equal and opposite to the centrifugal force of the mass. This condition of equilibrium is shown

[1] Civil-Ingenieur, 1895, p. 333.
[2] The Steam Turbine, Stodola, p. 183.
[3] Engineering (London), 1909, vol. 88, p. 135.

in Fig. 2, where the center of gravity is rotating at the radius r, and the shaft rotating in a bowed condition at the radius or deflection $(r\text{-}a)$. Let $\Delta = \frac{W\ K}{E\ I}$ – static deflection of shaft, if horizontal, and p (angular velocity) $= \frac{2\ \pi}{60\ N}$, where N = r. p. m. The centrifugal force of the center of gravity is mrp^2. This centrifugal force would produce a deflection of $m\ r\ p^2 \frac{K}{E\ I} = r\ p^2 \frac{W\ K}{g\ E\ I} = r\ p^2 \frac{\Delta}{g}$, where g is gravity. But the shaft deflection opposing the centrifugal force is, for equilibrium $(r\text{-}a)$. This gives the equation

$$r - a = r \frac{p^2\ \Delta}{g}$$

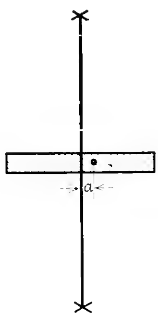


FIG. 1 CONCENTRATED LOAD ON VERTICAL SHAFT AT REST

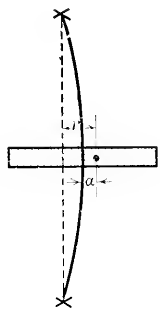


FIG. 2 CONCENTRATED LOAD ON VERTICAL SHAFT IN MOTION

which solved for r gives

$$r = \frac{\frac{ga}{\Delta}}{\frac{g}{\Delta} - p^2} \quad \text{......................(1)}$$

7 This equation, with values of r plotted against p, is shown in dotted lines in Fig. 3. As the angular speed p increases from zero, the radius or deflection r increases, until r becomes theoretically infinite when

$$p^2 = \frac{g}{\Delta}$$

This is the condition of maximum vibration produced by the shaft, and the critical number of revolutions is found from the equation

$$p^2 = \frac{g}{\Delta}$$

$$\left(\frac{2\pi}{60}N\right)^2 = \frac{32.2 \times 12}{\Delta}$$

$$N = \frac{187.7}{\sqrt{\Delta}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

for inch, pound, minute, units.

8 Referring to the curve beyond the critical-speed value, r becomes negative, and as the value of p is increased r approaches the

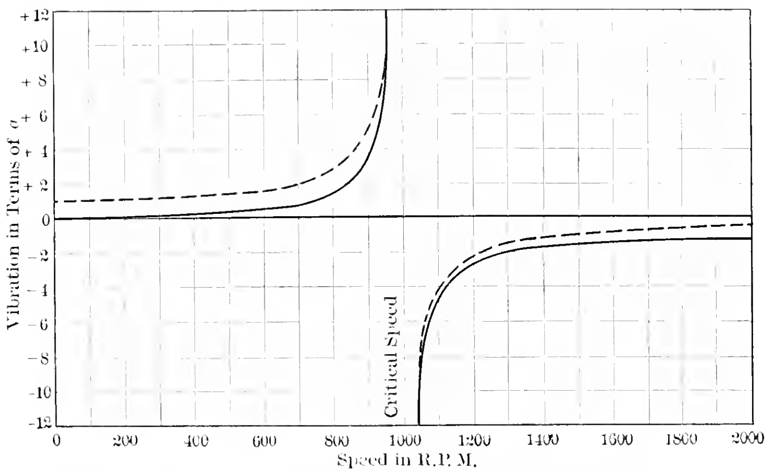


FIG. 3 AMPLITUDE OF VIBRATION WITH SINGLE CONCENTRATED LOAD (FIGS. 2 AND 4).

DOTTED LINE FOR EQUATION 1. SOLID LINE FOR EQUATION 4

limit of zero; in other words, above the critical speed the center of gravity revolves inside the bow of the shaft, or in a smaller circle than the shaft center; and the tendency of the rotating mass is to rotate about its own center of gravity, and not about the mechanical center. It approaches its center of gravity as a limit for infinite speed.

9 The natural time of vibration of a loaded shaft is

$$t = 2\pi\sqrt{\frac{\Delta}{g}}$$

and the number of natural vibrations per minute is

$$\frac{60}{t} = \frac{60}{2\pi}\sqrt{\frac{g}{\Delta}}$$

which is the same as N in Equation 2, the critical number of revolutions. Thus for a single concentrated load the critical-speed phenomena occur when the revolutions synchronize with the natural period of vibration of the shaft. No satisfactory explanation has been given of the detail action at the critical speed, or of the manner in which the center of gravity passes from the outside to the inside of the bow of the shaft. Theoretically the deflection or bow of the shaft becomes infinite at the critical speed. Practically it does not, because of the resistance of the air and probably the need of the factor of time to accumulate energy.

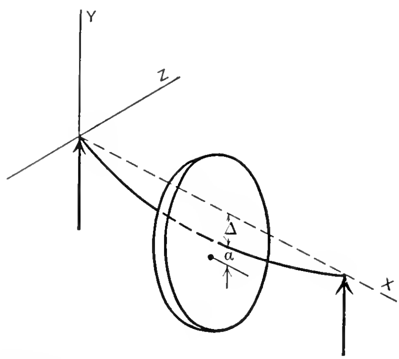


Fig. 4 Concentrated load on Horizontal Shaft

10 In machines where the normal running speed is higher than the critical speed, the shaft is made just strong enough to withstand the deflection in passing through the critical speed, and as weak or flexible as possible for the smooth running above the critical speed. The weaker the shaft, the lower the critical speed, the nearer approach to rotation about the center of gravity, and the less bow or deflection in the shaft.

11 This solution is satisfactory so far as the critical value and deflection of the rotating mass is concerned; and it affords a simple explanation of the actions of a rotating body. But in the design of a machine the vibrations of the frame or supporting structure are of equal or greater importance. The shaft rotating in its bowed condition has a reaction on the bearing points, the reaction rotating with

the shaft. This force is the impressed vibration that causes the frame to vibrate. If we determine the shaft deflection during rotation, or the location of the shaft axis at any instant, we can find the amount of the force of the shaft, or the impressed vibration on the frame.

12 When coördinate axes, as shown in perspective in Fig. 4, are taken, and the location and motion of the shaft center at any instant are determined, the force impressed upon the frame is measured by the coördinates of the shaft center. If we sum the forces along each axis, the solution gives us a form of compound harmonic vibration. This same method affords a comparatively easy algebraic solution for two loads; and is applied equally well to horizontal and vertical shafts

SINGLE CONCENTRATED LOADS

13 For the condition shown in perspective in Fig. 4, Δ is the static deflection at the disc load when the shaft is horizontal, and a the distance from the shaft center to the center of gravity. To simplify the

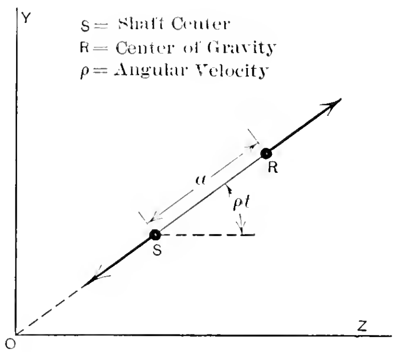


FIG. 5 CONCENTRATED LOAD ON HORIZONTAL SHAFT (FIG. 4)

calculations consider the shaft in a vertical position. It will be later shown that the same formulæ apply to horizontal shafts. Pass the YZ plane (Fig. 5) through the disc perpendicular to the shaft. When at rest the center of the vertical shaft is at the origin O. When in motion, at a given time the shaft center is at S, with the coördinates (yz); and the center of gravity is at R, a constant distance a from S. Due to the turning of the shaft, the point R revolves around S with the angular velocity p, so that the angle turned through is pt.

14 The force acting on the point S is the spring of the shaft towards the zero position. This is $\frac{W}{\Delta} OS$ where $\frac{W}{\Delta}$ is the force of the

shaft per unit of deflection. Since the force from S acts towards the origin, for equilibrium of moments about O the centrifugal force of the disc at R must act in a line through the origin. Also for equilibrium of the two forces they must act in line with each other, be equal in value and be opposed in direction. Then for R to turn about S with the angular velocity p, R must revolve about the origin with the same angular velocity, and in a circle with center at O.

15 The centrifugal force acting at R is $mp^2\,\overline{OR}$. The component parallel to the Y-axis is $mp^2\,(y + a \sin pt)$; and to the Z axis is $m\,p^2\,(z + a \cos pt)$. The spring of the shaft acting at S is $\frac{W}{\varDelta}\,\overline{OS}$, with a component parallel to the Y-axis of $-\frac{W}{\varDelta}\,y$; and to the Z-axis, $-\frac{W}{\varDelta}\,z$. The sum of these forces along the Y-axis is

$$mp^2\,(y + a \sin pt) - \frac{W}{\varDelta}\,y = O$$

and for the Z-axis

$$mp^2\,(z + a \cos pt) - \frac{W}{\varDelta}\,z = O$$

Dividing by m and solving for y and z these equations give

$$y = \frac{ap^2}{\frac{g}{\varDelta} - p^2} \sin pt \quad \ldots\ldots\ldots\ldots\ldots (3)$$

$$z = \frac{ap^2}{\frac{g}{\varDelta} - p^2} \cos pt \quad \ldots\ldots\ldots\ldots\ldots (4)$$

INTERPRETATION OF EQUATIONS

16 Equations 3 and 4 determine the motion or path of the shaft center. Taken together they are the equations of a circle with center at the origin. Taken separately, the equations are of the form of simple harmonic motion, with a forced vibration of $a \sin pt$ along the Y-axis, and $a \cos pt$ along the Z-axis. $p = \frac{2\pi}{60}$ times the frequency of vibration. The coefficients of the sine and cosine are the amplitude of the vibration along each axis. These are plotted in full lines in

Fig. 3. The amplitude of vibration, being the same for both axes, contains only the independent variable p. The amplitude will increase as the speed or p increases, until the vibration becomes infinite when $\frac{g}{\Delta} - p^2 =$ zero. This is the same critical-speed condition as in the previous solution, Equation 2. Beyond the infinite value the coefficients become negative and decrease, becoming smaller the higher the speed.

17 This can have the physical interpretation that before the critical speed is reached the center of gravity revolves outside of, or in a larger circle than, the mechanical center of the shaft. Beyond the critical-speed point, the center of gravity rotates inside of, or in a smaller circle than, the shaft center.

18 As previously shown, the critical speed occurs when the rotation synchronizes with the natural period of vibration of the loaded shaft. It may be seen from the curve that when the frequency of the forced vibration $\frac{60}{2\pi}p$ is nearly equal to the frequency of the natural vibration $\frac{60}{2\pi}\sqrt{\frac{g}{\Delta}}$ we have a similar state of things to that which gives rise to *resonance* in acoustic instruments and electrical circuits.

19 The natural period of vibration and the forced vibration are the same for either a vertical or a horizontal position of the shaft, so that the same critical-speed formulæ apply for either position. When vertical, the center of the vibration or of the rotation is at $y = 0$, $z = 0$; when horizontal, the center of the vibration along each axis is at $y = -\Delta$, $z = 0$. The horizontal position is equivalent to a change of coördinate axes from $y = 0$ to $y = -\Delta$, so that Equation 3 becomes

$$y = \frac{ap^2}{\frac{g}{\Delta} - p^2}\sin pt - \Delta \qquad \text{(3a)}$$

20 Vibration is caused by an unbalance of the body, or by the center of gravity not coinciding with the mechanical center of the shaft. The centrifugal force of the unbalance causes an accelerating force along each axis, or a forced vibration of a amplitude. This forced vibration causes the shaft to vibrate along each axis with the amplitude of $\frac{ap^2}{\frac{g}{\Delta} - p^2}$. This shaft vibration is in turn the vibration

that is forced on the frame or supporting structure and causes it to vibrate. This latter value is therefore the vibration to be considered in the design of machines. Comparing the two curves of Fig. 3 it will be noted that at zero speed the vibration in Equation 1 is a; in Equation 4 it is zero. Beyond the critical speed, Equation 1 approaches zero; Equation 4 approaches a. This difference is due to Equation 1 considering the motion of the center of gravity, and Equation 4 the motion of the shaft center. Equation 4 is the vibration impressed on the frame and therefore the value to be considered.

TWO CONCENTRATED LOADS

21 Equations covering any two concentrated loads, with either two or three bearing supports, may be developed by the same method as in the previous case. Take the condition shown in Fig. 6, with two discs for concentrated loads and three bearing points. To distinguish

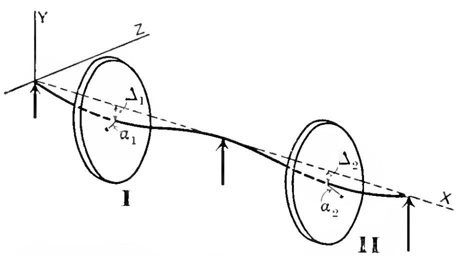


FIG. 6 TWO CONCENTRATED LOADS ON HORIZONTAL SHAFT

symbols, let the Y Z plane passing through disc I be represented by sub-letters 1, and the plane through disc II by sub-letters 2. To determine the influence one disc has upon the other the equations $F_1 = K_1\, y_1 + K_3\, y_2$ and $F_2 = K_2\, y_2 + K_3\, y_1$ are taken, where y_1 and y_2 are any positions of the shaft deflections on the Y-axis, and F_1 and F_2 are the shaft forces due to the deflections which act toward the unloaded or zero position. K_1, K_2 and K_3 are constants for a given shaft and can be deduced from the deflection equations of beams for different loads and supports. Assume the coördinates of the shaft center in any position y_1, z_1, in the plane through disc I and y_2, z_2 in the plane through disc II. Take the distances from the centers of gravity to the shaft centers to be a_1 and a_2 and their directions to differ by x deg. on the Y Z plane. The forces acting on the discs when the shaft is vertical are:

First, centrifugal force:

Plane I, Y-axis, $m_1 p^2 (y_1 + a_1 \sin pt)$;
Z-axis, $m_1 p^2 (z_1 + a_1 \cos pt)$.
Plane II, Y-axis, $m_2 p^2 [y_2 + a_2 \sin (pt + \alpha)]$;
Z-axis, $m_2 p^2 [z_2 + a_2 \cos (pt + \alpha)]$.

Second, reaction or spring of the shaft:

Plane I, Y-axis, $K_1 y_1 + K_3 y_2$; Z-axis, $K_1 z_1 + K_3 z_2$.
Plane II, Y-axis, $K_2 y_2 + K_3 y_1$; Z-axis, $K_2 z_2 + K_3 z_1$.

The summation of these forces along the axes gives the following equations:

$$m_1 p^2 (y_1 + a_1 \sin pt) - K_1 y_1 - K_3 y_2 = O.$$
$$m_1 p^2 (z_1 + a_1 \cos pt) - K_1 z_1 - K_3 z_2 = O.$$
$$m_2 p^2 [y_2 + a_2 \sin (pt + \alpha)] - K_2 y_2 - K_3 y_1 = O.$$
$$m_2 p^2 [z_2 + a_2 \cos (pt + \alpha)] - K_2 z_2 - K_3 z_1 = O.$$

The solution of these equations gives:

$$y_1 = A \sin pt - B \cos pt \qquad [5]$$
$$z_1 = B \sin pt + A \cos pt \qquad [6]$$
$$y_2 = C \sin pt + D \cos pt \qquad [7]$$
$$z_2 = -D \sin pt + C \cos pt \qquad [8]$$

where

$$A = \frac{(K_2 - m_2 p^2) m_1 a_1 p^2 - K_3 m_2 a_2 p^2 \cos \alpha}{(K_1 - m_1 p^2)(K_2 - m_2 p^2) - K_3^2}$$

$$B = \frac{K_3 m_2 a_2 p^2 \sin \alpha}{(K_1 - m_1 p^2)(K_2 - m_2 p^2) - K_3^2}$$

$$C = \frac{(K_1 - m_1 p^2) m_2 a_2 p^2 \cos \alpha - K_3 m_1 a_1 p^2}{(K_1 - m_1 p^2)(K_2 - m_2 p^2) - K_3^2}$$

$$D = \frac{(K_1 - m_1 p^2) m_2 a_2 p^2 \sin \alpha}{(K_1 - m_1 p^2)(K_2 - m_2 p^2) - K_3^2}$$

INTERPRETATION OF EQUATIONS

22 Equations 5 to 8 are of the form of harmonic motion along their respective axes. Equations 5 and 6 taken together (also Equations 7 and 8) are equations of a circle with center at the origin, the radius of the circle being $\sqrt{A^2 + B^2}$.

23 The coefficients which represent the radii in rotation, or the amplitude of vibration, have the same denominators. The value of the coefficients becomes infinite when the denominators equal zero, which is the critical-speed condition. That is,

$$(K_1 - m_1 p^2)(K_2 - m_2 p^2) - K_3^2 = O.$$

$$p = \sqrt{\frac{g}{2}\left[\frac{K_1}{W_1} + \frac{K_2}{W_2} \pm \sqrt{\left(\frac{K_1}{W_1} - \frac{K_2}{W_2}\right)^2 + \frac{2K_3^2}{W_1 W_2}}\right]} = \frac{2\pi}{60} N$$

$$N = 132.3\sqrt{\frac{K_1}{W_1} + \frac{K_2}{W_2} \pm \sqrt{\left(\frac{K_1}{W_1} - \frac{K_2}{W_2}\right)^2 + \frac{2K_3^2}{W_1 W_2}}} \qquad \ldots\ldots\ldots[9]$$

for inch, pound, minute units.

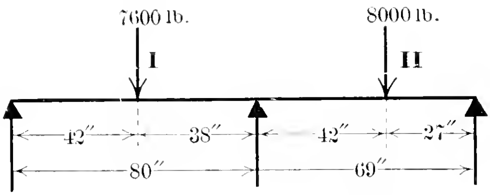


FIG. 7 CONDITION OF LOAD ON SHAFT (FIG. 6)

24 The ± sign of this equation gives two values of critical speed. This equation is general for two concentrated loads regardless of the method of support, for either two of three bearings.

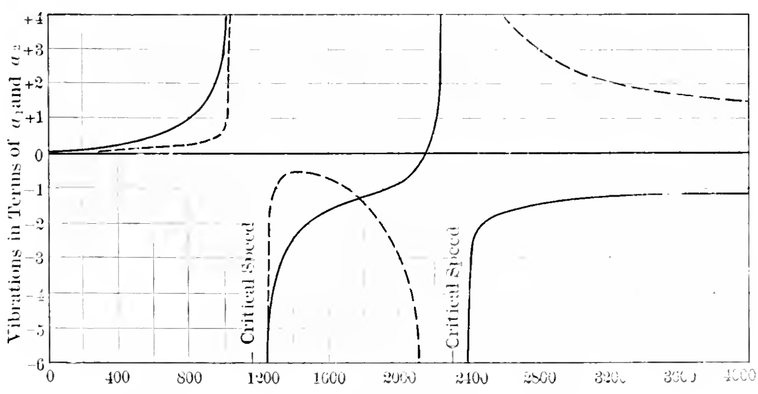


FIG. 8 AMPLITUDE OF VIBRATION WITH TWO CONCENTRATED LOADS (FIGS. 6 AND 7)

SOLID LINE FOR LOAD I; DOTTED LINE FOR LOAD II

25 When the unbalances a_1 and a_2 of the centers of gravity of both loads lie in the same plane, either on the same or opposite sides of the shaft, so that the angle α is zero or π, the coefficient B becomes zero and the radius of the circle of the shaft path is A. This gives below the critical-speed value the smallest circle when the unbalances are on the same side, or α equal to zero degrees; above the critical speed, π gives the smallest circle.

26 The properties of Equations 5 and 8 can be shown more fully by an example. For the conditions given in Fig. 7 the amplitude of the vibrations is plotted in Fig. 8. This machine showed excessive vibration between 1100 and 1200 r.p.m., when not in nearly perfect balance. It could not be speeded up to the second critical speed, the second value being too far above the running speed. The solid curve is the vibration of Load I; the dotted curve is the vibration of Load II. The amount of vibration is in terms of the unbalance a_1 and a_2.

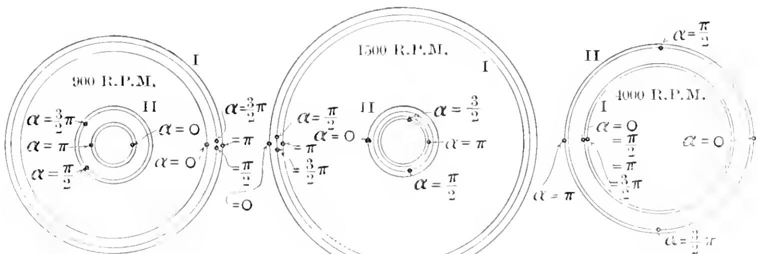


FIG. 9, 10, 11 PATH AND RELATIVE LOCATION OF SHAFT CENTERS FOR DIFFERENT ANGLES OF UNBALANCE

For the same unbalance, Load I, having the weaker portion of the shaft, has the largest vibrations until the first critical speed is reached. Beyond the first critical value the vibrations of Load II become large and influence the vibrations of Load I, reducing them through zero from a negative to a positive value. Beyond the second critical speed, Load II with the stiffer shaft has the larger vibrations.

27 Another interesting thing is the relative location of the shaft centers at any given time. Figs. 9, 10 and 11 show the paths of the shaft centers and their location on the circles, for the angle between the unbalances of $\alpha = 0, \frac{1}{2}\pi, \pi$ and $\frac{3}{2}\pi$, when $pt = 0, 2\pi$, etc. The rotation of the points on all circles is in the same direction as the rotation of the machine. When below the critical speed (Fig. 9),

Load I on the weaker shaft, or the shaft with the largest static deflection, rotates in the larger circle. Note the relative positions of the shaft centers for different values of α: and the influence the larger circles have upon Load II in forcing the unbalances towards opposite sides of the shaft as shown by the positions for $\alpha = \frac{1}{2}\pi$ and $\frac{3}{2}\pi$. Between the two critical speeds (Fig. 10), the positions for all values of α have turned through 180 deg., except Load II, $\alpha = \frac{1}{2}\pi$ and $\frac{3}{2}\pi$. Above the second critical speed the positions of Load II turn through another 180 deg., while Load I is unchanged. Here the stiffer shaft, or Load II, has the larger circles of rotation.

CONSTANTS FOR TWO LOADS

28 As the sixty-nine formulæ given in the table for calculations cannot be derived for want of space, an example will be given to illustrate the method. Take the condition of two loads just considered, using the letters given in Fig. 12 for dimensions and weights. The

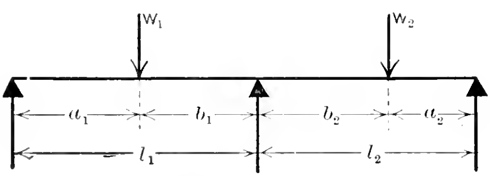


FIG. 12 CONDITIONS OF LOADING

force of the spring of the shaft is $F_1, = K_1\, y_1 + K_3\, y_2$ at W_1, for any deflections y_1 and y_2; and $F_2 = K_2\, y_2 + K_3\, y_1$ at W_2 for any position y_1 and y_2. The standard equations for deflections at the loads are:

$$\Delta_1 = \frac{a_1\, b_1}{6E\, Il_1}\left[2\, a_1\, b_1\, W_1 - m\,(l_1 + a_1)\right]$$

$$\Delta_2 = \frac{a_2\, b_2}{6E\, Il_2}\left[2\, a_2\, b_2\, W_2 - m\,(l_2 + a_2)\right]$$

$$m = \frac{1}{2\,(l_1 + l_2)}\left[\frac{W_1\, a_1\, b_1}{l_1}(l_1 + a_1) + \frac{W_2\, a_2\, b_2}{l_2}(l_2 + a_2)\right]$$

Making variable by changing Δ_1 to y_1, Δ_2 to y_2, W_1 to F_1, W_2 to F_2, and solving for F_1 and F_2, gives equations of the above form, where

$$K_1 = \frac{C\ l_1^2}{a_1^2\ b_1^2}[4\ l_2\ (l_1 + l_2) - (l_2 + a_2)^2]$$

$$K_2 = \frac{C\ l_2^2}{a_2^2\ b_2^2}[4\ l_1\ (l_1 + l_2) - (l_1 + a_1)^2]$$

$$K_3 = \frac{C\ l_1\ l_2}{a_1\ b_1\ a_2\ b_2}(l_1 + a_1)\ (l_2 + a_2)$$

$$C = \frac{3\ E\ I}{4\ l_1\ l_2\ (l_1 + l_2) - l_1\ (l_2 + a_2)^2 - l_2\ (l_1 + a_1)^2}$$

Constants for other dimensions, loads and supports, may be derived from the deflection formulæ in a similar manner.

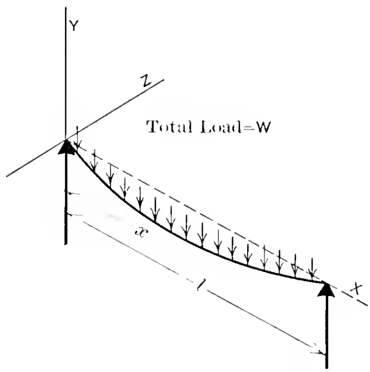


Fig. 13 Shaft with Uniform Load

DISTRIBUTED LOADS

29 All critical speed formulæ so far developed for distributed loads are based on the equation in Mechanics that

$$E\,I\,\frac{d^4\,y}{d\,x^4} = \text{the weight or force } \textit{on} \text{ a unit length of beam}$$

and there is an unbalance caused by the center of gravity not coinciding with the shaft center.

30 To simplify the calculations, assume the conditions of Fig. 13, of a shaft with constant diameter uniformly loaded over its entire length by a load, as disc wheels, which will not affect the flexibility of the shaft; and that the centers of gravity of all the discs lie in the same plane and on the same side of the shaft, at a constant distance *a*

from the shaft center, similar to the single disc in Fig. 4. W = total weight of shaft and discs.

31 Taking any unit length along the X axis, its mass is $\frac{W}{l\,g}$. Assume the center of rotation to be at the origin of the axes when the shaft is vertical. The centrifugal force of the mass of unit length is $\frac{W}{l\,g}\,p^2$ times the radius to center of gravity. This radius projected on the Y axis is $(y + a \sin pt)$ and on the Z axis is $(z + a \cos pt)$, where y and z are coördinates of the shaft center for the shaft in any position of rotation.

32 The forces acting on a unit length, projected on the axes, are: First, centrifugal force: Y axis, $\frac{W\,p^2}{l\,g}\,(y + a \sin pt)$; Z axis, $\frac{W\,p^2}{l\,g}$ $(z + a \cos pt)$.

The second force, the spring of the shaft, does not enter as we are considering the forces acting *on* the shaft, and not the reaction of the shaft.

33 The equation in Mechanics of the forces acting on a unit length gives for the Y axis:

$$E\,I\,\frac{d^4y}{dx^4} = \frac{W}{l}\,\frac{p^2}{g}\,(\,y + a \sin pt)$$

and for the Z axis:

$$E\,I\,\frac{d^4\,z}{d\,x^4} = \frac{W\,p^2}{l\,g}\,(z + a \cos pt)$$

The general solutions of these equations are:

$$y = [Fe^{kx} + Ge^{-kx} + H \cos kx + J \sin kx - a] \sin pt \ldots\ldots [10]$$

$$z = [Fe^{kx} + Ge^{-kx} + H \cos kx + J \sin kx\text{-}a] \cos pt \ldots\ldots\ldots\ldots [11]$$

where

$$k = \sqrt[4]{\frac{W\,p^2}{E\,I\,g\,l}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots [12]$$

e = the base of the natural system of logarithms, and the capital letters are constants determined by the conditions imposed on the equations by the supports, etc., as shown in the following special cases.

SHAFT SUPPORTED AT BOTH ENDS

34 A shaft supported at both ends, as shown in Fig. 13, either vertical or horizontal, imposes the conditions of deflection y, and moment $EI\frac{d^2y}{dx^2}$, both equal to zero at the supports, or when x equals zero and when x equals l. This gives four equations with four unknown constants as follows:

For $x = 0$, $y = 0$

$$0 = F + G + H - a$$

For $x = 0$, $\frac{d^2y}{dx^2} = 0$

$$0 = F + G - H$$

For $x = l$, $y = 0$

$$0 = Fe^{kl} + Ge^{-kl} + H\cos kl + J\sin kl - a$$

For $x = l$, $\frac{d^2y}{dx^2} = 0$

$$0 = Fe^{kl} + Ge^{-kl} - H\cos kl - J\sin kl$$

The solution of these four equations gives

$$F = -\frac{a}{2}\left(\frac{e^{-kl} - 1}{e^{kl} - e^{-kl}}\right) \qquad G = \frac{a}{2}\left(\frac{e^{kl} - 1}{e^{kl} - e^{-kl}}\right)$$

$$H = \frac{a}{2} \qquad J = \frac{a}{2}\left(\frac{1 + \cos kl}{\sin kl}\right)$$

These values substituted in the general equations 10 and 11 for distributed loads give values for y and z which represent the path of the shaft center for any point x along the length. The coefficients of $\sin pt$ and $\cos pt$ are the amplitude of vibration along each axis, or the radius of the circle in which any point on the shaft center rotates. These coefficients become infinite or have the critical speed value when $\sin kl = 0$, or whenever $kl = \pi, 2\pi, 3\pi$, etc. Since p is proportional to k^2 by equation 12 we have an infinite number of critical speeds which have the ratio $1 : 2^2 : 3^2 : 4^2 \ldots$ The first or lowest critical speed is found from

$$k\,l = \pi = \sqrt[4]{\frac{W\,p^2}{E\,I\,g\,l}}\;l$$

For a circular shaft of d in. diameter, $E = 29,000,000$, $g = 386$,

$$p = \frac{2\pi}{60} N_1$$

$$N_1 = 2,232,510\, d^2 \sqrt{\frac{1}{W\, l^3}}$$

for inch, pound, minute units. For a shaft with its own weight only, $W = 0.28 \frac{\pi}{4} d^2\, l$. Substituting gives

$$N_1 = 4,760,000 \frac{d}{l^2}$$

35 The values of the constants F, G, H and J, inserted in Equation 10, show that the shaft rotates in a bowed condition up to the

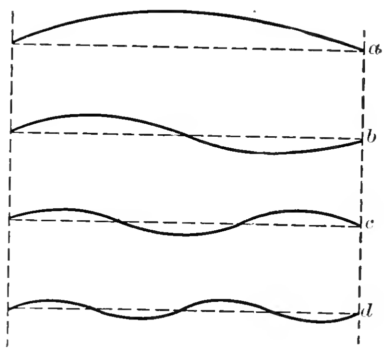


Fig. 14 Condition of Rotation at Various Speeds

first critical speed as shown in Fig. 14a; between the first and second critical speeds as in Fig. 14b; between the second and third critical speeds as in Fig. 14c; and so on.

SHAFT FIXED AT BOTH ENDS

36 A shaft with uniform load between long rigid bearings, we can treat as a beam fixed at both ends and impose the conditions upon Equations 10 and 11 of the deflection $y = 0$, when $x = 0$ and when $x = l$; and the tangent to deflection curve $\frac{dy}{dx} = 0$, when $x = 0$ and

when $x = l$. Solving these four equations for the unknown constants, each constant has the denomination of $2 - (e^{kl} + e^{-kl}) \cos kl$. y and z become infinite when the denominator equals zero, or

$$\cos kl = \frac{2}{e^{kl} + e^{-kl}} = \text{sech } kl$$

37 To satisfy this equation kl is nearly $\frac{3}{2}\pi, \frac{5}{2}\pi, \frac{7}{2}\pi, \frac{9}{2}\pi \ldots$ The critical speeds have the ratio:

$$3^2 : 5^2 : 7^2 : 9^2 \quad \ldots . = 1 : 2.78 : 5.45 : 9 \ldots .$$

The first critical speed is when

$$kl = \frac{3}{2}\pi = \sqrt[4]{\frac{W}{E} \frac{p^2}{I\,gl}}\; l$$

$$N_1 = 4{,}979{,}250\, d^2 \sqrt{\frac{1}{W\, l^3}}$$

and for a shaft with its own weight only, $N_1 = 10{,}616{,}740 \frac{d}{l^2}$ in inch, pound, minute, units.

OVERHANGING SHAFT FIXED AT ONE END

38 Taking the origin of the coördinate system at the support, we can impose upon Equations 10 and 11 the conditions of a cantilever beam; that is, the deflection $y = 0$ for $x = 0$; tangent to elastic curve $\frac{dy}{dx} = 0$ for $x = 0$; the bending moment $\frac{d^2 y}{dx^2} = 0$ for $x = l$; and the shear $\frac{d^3 y}{dx^3} = 0$ for $x = l$. Solving these four equations for the unknown constants, each constant has the denominator of $2 + (e^{kl} + e^{-kl}) \cos kl$. y and z are infinite when the denominator is zero, or when

$$\cos kl = -\frac{2}{e^{kl} + e^{-kl}} = -\text{sech } kl$$

39 The smallest value of kl to satisfy this equation is 1.8751. The next values are nearly $\frac{3}{2}\pi, \frac{5}{2}\pi, \frac{7}{2}\pi \ldots\ldots$ Critical speeds have

the ratio of 1 : 6.34 : 17.6 : 43.6...... The first critical speed is when

$$kl = 1.8751 = \sqrt{\frac{Wp^2}{E\ I\ gl}}\ l$$

$$N_1 = 795{,}196\ d^2 \sqrt{\frac{1}{W\ l^3}}$$

and for a shaft with its own weight only, $N_1 = 1{,}695{,}514\ \frac{d}{l^2}$ in inch, pound, minute, units.

SHAFT FIXED AT ONE END AND SUPPORTED AT THE OTHER

40 With the origin of the coördinate system at the fixed end of the shaft, we can place on Equations 10 and 11 the condition of deflection $y = 0$ for $x = 0$ and for $x = l$; the tangent to the elastic curve $\frac{dy}{dx} = 0$ for $x = 0$; and the moment $\frac{d^2y}{dx^2} = 0$ for $x = l$. Solving these four equations for the unknown constants, each constant has a denominator of cosh kl sin kl $-$sinh kl cos kl. which equals zero for the critical speeds; or tan kl = tanh kl

$$kl = \frac{5}{4}\pi, \frac{9}{4}\pi, \frac{13}{4}\pi,$$

The critical speeds have the ratio

$$5^2 : 9^2 : 13^2 : 17^2$$

or

$$1 : 3.24 : 6.8 : 11.6$$

The first critical speed is for

$$kl = \frac{5\pi}{4} = \sqrt[4]{\frac{W\ p^2}{EIgl}}\ l$$

$$N_, = 3{,}482{,}715\ d^2 \sqrt{\frac{1}{W\ l^3}}$$

and for shaft with its own weight only

$$N_1 = 7{,}021{,}600\ \frac{d}{l^2}$$

for inch, pound, minute, units.

GENERAL OBSERVATIONS

41 All formulæ developed for critical speed, for both concentrated and distributed loads, apply to vertical shafts as well as horizontal. When the shaft is vertical the equation for the Y-axis only is affected, the value of y dropping the $(-\varDelta)$, the coefficient of sin pt being unchanged. Since this coefficient determines the critical speed value, we have the same critical speed for horizontal as for vertical shafts. Although some formulæ use the static deflection $\varDelta$, this is an equivalent deflection and can be used for vertical shafts by considering them horizontal.

42 The obliquity of the loads caused by the bending of the shaft has not been considered. When the load is near the bearings, as shown in Fig. 15, the load passes from the full line to the dotted line position, and back to the full line, for each revolution. The inertia of the disc offers a resistance to this change of position; and this resistance raises

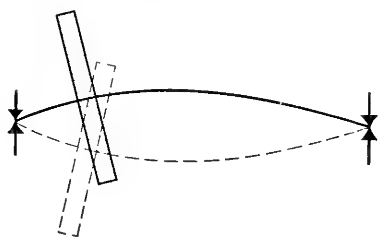


FIG. 15 OBLIQUITY OF LOAD DURING ROTATION

the value of the critical speed. But the obliquity does not introduce a considerable error if the loads are nearly half way between the bearings.

43 Theoretically the vibrations become infinite at the critical speed; actually they do not, but the vibrations are at a maximum point. As shown by the curves of Fig. 3 and Fig. 8, the vibrations will begin at a certain speed, increase as the speed increases, and with still increasing speed will after a while die away. The vibrations may be felt over a considerable range, and the exact point of maximum value is difficult to detect. It is therefore advisable to keep the running speed at least 20 per cent away from the critical value; and if the normal speed is between two critical values, as in Fig. 8, careful calculations should be made for the point of minimum vibration.

44 Under ordinary circumstances the speed should be considerably below the critical value, as then the balance need not be particu-

larly good. When the speed is considerably above the critical value, the vibration is almost proportional to the unbalance (a in the equations) and the flexibility of the shaft; and the balance should be good, to prevent injury to the shaft and excessive vibration when passing through the critical speed.

45 A machine may be run very close to or at the critical speed, but the alignment and play of bearings, all mechanical details and the balance will require extra care, so that a troublesome and more expensive machine results before it is in good operating condition. The machine will run smoothly for a considerable time, until some mechanical fit or play cause a slight unbalance and immediately sets up excessive vibrations.

46 All of the solutions of shaft deflection in this paper are in the mathematical form of a harmonic vibration produced by the impressed vibration of the unbalance of load. Harmonic vibrations of this form have a special solution by calculus when p^2 equals the natural period of vibration of the shaft, or in all the cases considered, the critical-speed period. For Equations 3 and 4, when $\frac{g}{\Delta} = p^2$, the special solutions are

$$y = \frac{a\,t}{2\sqrt{\frac{g}{\Delta}}} \sin \sqrt{\frac{g}{\Delta}}\, t$$

$$z = \frac{a\,t}{2\sqrt{\frac{g}{\Delta}}} \cos \sqrt{\frac{g}{\Delta}}\, t$$

These equations show that during the critical-speed period the vibrations increase theoretically with the time, so that in machines running above the critical speed there is less vibration at the critical-speed point when it is rapidly passed over. The equations also show a transfer of energy; the kinetic energy from the unbalance being transformed into the potential energy of the shaft deflection, so that a machine with *nearly perfect* balance may run smoothly for considerable time at the critical speed before vibrations appear. The writer has not seen or had sufficient proof of the action of these two equations, but they may explain some of the peculiar phenomena observed in the vibration of certain machines.

47 With excessive vibration in passing through the critical speed

there is a considerable tendency to spring the shaft by giving it a permanent set. This is most dangerous when the machine is first started, before it has a running balance. Partly for this reason many designers use the more expensive nickel-steel forged shaft instead of carbon steel. With due consideration of the smaller coefficient of expansion of nickel-steel, in distorting large shafts when all parts are not at the same temperature, and of the fatigue or reversal of fibre stress in horizontal shafts, the machine and shaft can be so proportioned for smooth running that the finer grade of shaft steel is not always necessary.

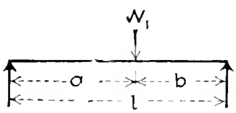
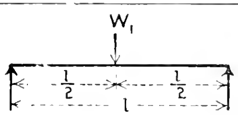
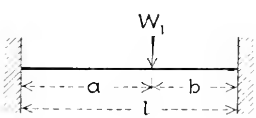
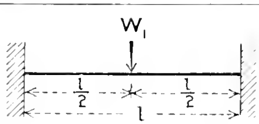
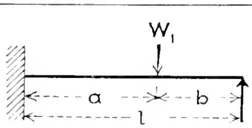
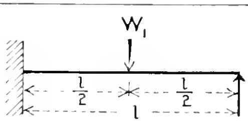
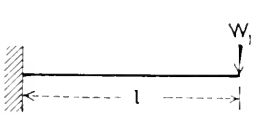
TABLE OF FORMULÆ

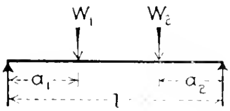
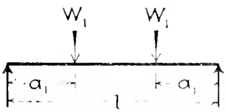
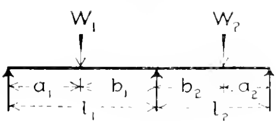
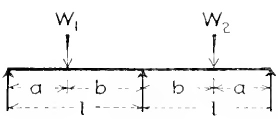
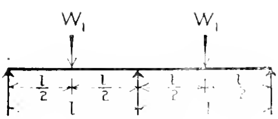
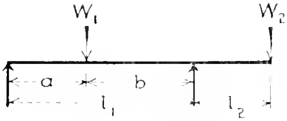
48 The formulæ developed in this paper have been transformed to suit a number of special conditions, and placed in tabulated form for convenient use. The data required for the solution of critical-speed problems are the same as those for shaft deflection at loads. As the shaft is usually of variable diameter, and its stiffness is increased by a long hub, an ideal shaft of uniform diameter and equal stiffness, or for the same deflection, must be assumed. The loads are usually concentrated with an ideal point of application. The weights and distances between bearings and loads are the same in the ideal as in the actual case. Experience has shown that when the largest shaft diameter and uniform load cover about one-third of the span, approximately the same deflection is given for the load concentrated with a uniform shaft of the largest diameter. The weight of the shaft can be divided among the concentrated loads. As formulæ have not been developed for more than two loads, when more than two loads are given they must be transformed into two resultant loads that would give the same deflection. For this case, two critical speeds are found, one of which is usually far from the working speed.

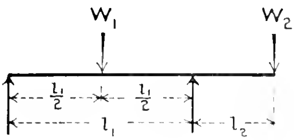
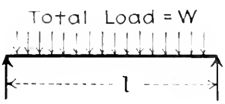
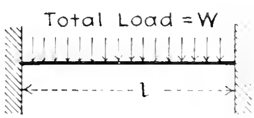
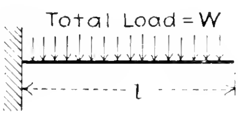
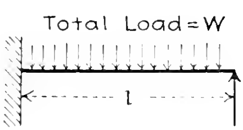
CRITICAL SPEED FORMULAE

WEIGHTS IN POUNDS, DIMENSIONS IN INCHES, VERTICAL SHAFTS CONSIDERED HORIZONTAL

N, N_1, N_2 = critical speeds in r.p.m.
Δ_1, Δ_2 = static deflections at W_1 and W_2 (shaft horizontal).
d = diameter of shaft (inches). E = 29,000,000.

Single Concentrated Load General Formulae	$N_1 = \frac{187.7}{\sqrt{\Delta_1}}$	1
	$N_1 = 387{,}000\frac{d^2}{ab}\sqrt{\frac{l}{W_1}}$ $N_1 = 187.7\sqrt{\frac{1}{\Delta_1}}$ $\Delta_1 = \frac{W_1 a^2 b^2}{3EIl}$	2 1 3
	$N_1 = 1{,}550{,}500 d^2\sqrt{\frac{1}{W_1 l^3}}$ $N_1 = 187.7\sqrt{\frac{1}{\Delta_1}}$ $\Delta_1 = \frac{W_1 l^3}{48EI}$	4 1 5
	$N_1 = 387{,}000 d^2\sqrt{\frac{l^3}{W_1 a^3 b^3}}$ $N_1 = 187.7\sqrt{\frac{1}{\Delta_1}}$ $\Delta_1 = \frac{W_1 a^3 b^3}{3EIl^3}$	6 1 7
	$N_1 = 3{,}100{,}850 d^2\sqrt{\frac{1}{W_1 l^3}}$ $N_1 = 187.7\sqrt{\frac{1}{\Delta_1}}$ $\Delta_1 = \frac{W_1 l^3}{192EI}$	8 1 9
	$N_1 = 775{,}200\frac{d^2 l}{ab}\sqrt{\frac{l}{W_1 a(3l+b)}}$ $N_1 = 187.7\sqrt{\frac{1}{\Delta_1}}$ $\Delta_1 = \frac{W_1 a^3 b^3}{12EIl^3}(3l+b)$	10 1 11
	$N_1 = 2{,}337{,}000\frac{d^2}{l}\sqrt{\frac{1}{W_1 l}}$ $N_1 = 187.7\sqrt{\frac{1}{\Delta_1}}$ $\Delta_1 = \frac{7}{768}\frac{W_1 l^3}{EI}$	12 1 13
	$N_1 = 387{,}000 d^2\sqrt{\frac{1}{W_1 l^3}}$ $N_1 = 187.7\sqrt{\frac{1}{\Delta_1}}$ $\Delta_1 = \frac{W_1 l^3}{3EI}$	14 1 15

Two Concentrated Loads General Formulae	N_1 and N_2 $=132.3\sqrt{\left(\frac{K_1}{W_1}+\frac{K_2}{W_2}\right)\pm\sqrt{\left(\frac{K_1}{W_1}-\frac{K_2}{W_2}\right)^2+\frac{4K_3^2}{W_1W_2}}}$	16
	$C=\frac{6EI}{(l-a_1-a_2)^2[l(3l-2a_1-2a_2)-(a_2-a_1)^2]}$ $K_1=C\frac{2}{a_1^2}l(l-a_2)^2$ $K_2=C\frac{2}{a_2^2}l(l-a_1)^2$ $K_3=C\frac{l(l^2-a_2^2-a_1^2)-a_1a_2(a_1-a_2)}{a_1a_2}$ N_1 and N_2 = Substitute in Equation 16	17 18 19 20
	$N_1=548{,}400\frac{d^2}{a_1(l-2a_1)}\sqrt{\frac{l}{W_1}}$ $N_2=548{,}400\frac{d^2}{a_1}\sqrt{\frac{l}{W_1(3l-4a_1)}}$ $N_2=187.7\sqrt{\frac{1}{\Delta_1}}$ $\Delta_1=\frac{W_1a_1^2}{6EI}(3l-4a_1)$	22 23 24 25
	$C=\frac{3EI}{4l_1l_2(l_1+l_2)-l_1(l_2+a_2)^2-l_2(l_1+a_1)^2}$ $K_1=\left(\frac{l_1}{a_1b_1}\right)^2C[4l_2(l_1+l_2)-(l_2+a_2)^2]$ $K_2=\left(\frac{l_2}{a_2b_2}\right)^2C[4l_1(l_1+l_2)-(l_1+a_1)^2]$ $K_3=\frac{l_1l_2}{a_1b_1a_2b_2}C(l_1+a_1)(l_2+a_1)$ N_1 and N_2 = Substitute in Equation 16	26 27 28 29
	$C=\frac{3EIl}{2a^2b^2[4l^2-(l+a)^2]}$ $K_1=K_2=C[8l^2-(l+a)^2]$ $K_3=C(l+a)^2$ N_1 and N_2 = Substitute in Equation 16	30 31 32
	$N_1=1{,}547{,}000d^2\sqrt{\frac{l}{W_1l^3}}$ $N_1=124.3\sqrt{\frac{1}{\Delta_1}}$ $N_2=2{,}337{,}000d^2\sqrt{\frac{l}{W_1l^3}}$ $N_2=187.7\sqrt{\frac{1}{\Delta_1}}$ $\Delta_1=\frac{7}{768}\frac{Wl^3}{EI}$	33 34 35 36 37
	$C=\frac{12EI}{a^2l_2^2[4b^2l_1(l_1+l_2)-(l^2-a^2)^2]}$ $K_1=Cl_1^2l_2^2(l_1+l_2)$ $K_2=Ca^2b^2l_1$ $K_3=\frac{C}{2}al_1l_2(l_1^2-a^2)$ N_1 and N_2 = Substitute in Equation 16 $\Delta_1=\frac{W_1a^2b^2}{3EIl_1}-W_2\frac{al_2}{6EIl_1}(l_1^2-a^2)$ $\Delta_2=\frac{W_2l_2^2}{3EI}(l_1+l_2)-W_1\frac{a\,l_2}{6EIl_1}(l_1^2-a^2)$	38 39 40 41 42 43

	$C = \frac{3EI}{l_1^3 l_2^2 (l_1+l_2) - \frac{9}{16} l_1^4 l_2^2}$	44
	$K_1 = 16 C l_2^2 (l_1+l_2)$	45
	$K_2 = C l_1^3$	46
	$K_3 = 3 C l_1^2 l_2$	47
	N_1 and N_2 = Substitute in Equation 16	
	$\Delta_1 = \frac{W_1 l_1^3}{48EI} - \frac{W_2 l_2 l_1^2}{16EI}$	48
	$\Delta_2 = \frac{W_2 l_2 (l_1+l_2)}{3EI} - \frac{W_1 l_2 l_1^2}{16EI}$	49
Distributed Loads.— Δ = Maximum Static Deflection.		
	$N_1 = 2{,}232{,}510\, d^2 \sqrt{\frac{I}{Wl^3}}$	50
	$N_1 = 211.4 \sqrt{\frac{1}{\Delta}}$	51
	$N_1 = 4{,}760{,}000 \frac{d}{l^2}$ (Shaft alone)	52
	$N = [1, 4, 9, 16, \text{Atc.}] N_1$	53
	$\Delta = \frac{5}{384} \frac{Wl^3}{EI}$	54
	$N_1 = 4{,}979{,}250\, d^2 \sqrt{\frac{I}{Wl^3}}$	55
	$N_1 = 245 \sqrt{\frac{1}{\Delta}}$	56
	$N_1 = 10{,}616{,}740 \frac{d}{l^2}$ (Shaft alone)	57
	$N = [1, 2.78, 5.45, 9, \text{Atc.}] N_1$	58
	$\Delta = \frac{Wl^3}{384EI}$	59
	$N_1 = 795{,}196\, d^2 \sqrt{\frac{I}{Wl^3}}$	60
	$N_1 = 167.6 \sqrt{\frac{1}{\Delta}}$	61
	$N_1 = 1{,}695{,}514 \frac{d}{l^2}$ (Shaft alone)	62
	$N = [1, 6.34, 17.6, 43.6, \text{Atc.}] N_1$	63
	$\Delta = \frac{Wl^3}{8EI}$	64
	$N_1 = 3{,}482{,}715\, d^2 \sqrt{\frac{I}{Wl^3}}$	65
	$N_1 = 209.7 \sqrt{\frac{1}{\Delta}}$	66
	$N_1 = 7{,}021{,}600 \frac{d}{l^2}$ (Shaft alone)	67
	$N = [1, 3.24, 6.8, 11.6, \text{Atc.}] N_1$	68
	$\Delta = \frac{Wl^3}{185EI}$	69

THE TRAINING OF MEN—A NECESSARY PART OF THE MODERN FACTORY SYSTEM

By Magnus W. Alexander, Published in The Journal for January 1910

ABSTRACT OF PAPER

The paper outlines briefly the educational policy of the General Electric Company at Lynn, Mass., where a systematic training is provided, suitable to all classes of people. The unskilled worker without particular education receives a training adequate to his immediate needs; the grammar school boy is initiated into the trades on the basis of a four years' course with educational instruction of a high school character; the high school graduate is trained for semi-professional service of a technical or business nature, on the basis of a three years' course with educational instruction of collegiate grade; and the college graduate is prepared for professional service of the highest order, on the basis of a two years' training of the character of a post-graduate course. An hour and a half to two hours must be spent in the classrooms every day, except Saturday, and except during parts of July and August, and classes meet during regular working hours, the students receiving the same compensation as during working hours. The apprentice training room is a trade school in the factory and permits of training under the most favorable conditions and expert supervision.

DISCUSSION

Prof. Ira N. Hollis said that this movement, which practically began ten or fifteen years ago, is bound to extend throughout the country. He referred to the city of Geneva, one of the best governed in the world, where the city council directs these courses of training, and said that the future would show whether our cities could undertake this. In the meantime these great companies are stepping into the gap.

2 The college graduate, as Mr. Alexander has pointed out, lacks practical knowledge. A committee appointed some years ago to represent all the engineering societies of England, recommended that every engineer spend at least one year in a commercial establishment before graduation, this year to follow the first year of

This paper was presented at Boston, March 11, 1910. The discussion is given in abstract only.

college work. Although this seems a prolongation, it is rather a shortening of the course, because of the value of the commercial contact. It might be difficult to get the larger firms to take men under such conditions, but it is probable that such firms would realize that they would profit very largely by the return of men thus trained into business, through their knowledge of the firm's products. Every industry and every side of our industrial life ought to have a school in an establishment where the product is made, not only for the workmen but for the graduates who are going to become engineers in that specialty.

H. S. Knowlton.[1] The industrial organization needs educational advantages among its workers. The public service corporation is coming to the same position, and within the last two or three years quite a number of companies working along street railway lines, or in central station operation, have taken this question up with considerable interest.

2 To speak specifically, perhaps one of the most interesting examples in this vicinity is afforded by the Boston Elevated Railway Company. About four years ago the company began a series of car-house foreman meetings, held monthly under the supervision of John Lindel, the superintendent of rolling stock and shops. At these meetings the defects of the cars are discussed, diagrams and charts are put on the blackboard, and the improvements in keeping rolling stock free from troubles from one year's end to another shown graphically before the men. After full discussion, the meeting is usually turned over to some representative of the operating department especially familiar with one line or another of the work, who either reads a paper or gives an informal address on some subject of special interest. Of the subjects discussed, three or four that may be cited are snow-plow maintenance, accidents, fire protection, gears and motor troubles.

3 The frank and free discussion of these topics in an intensely active operating company is bound to increase the efficiency of minor subordinate officials. Last October the Boston Elevated Railway Company started another series of meetings for its pit-men and car-house foremen and some selected shop employees. The object of the meetings held weekly has been to increase the theoretical knowledge of the work, in the belief that some classes of employees need

[1] Technical Journalist.

this, while the college graduate perhaps needs an increase in practical knowledge. Subjects that have been taken up in these lectures are static electricity, magnetism, measurement of currents, induction currents, electrical considerations in the design of direct-current motors, rheostatic control, multiple-unit control, air-brake equipment, control equipment, track maintenance, blue-print reading-records to maintain personal efficiency, and the design of various electric motors used on the system for car propulsion. Furthermore, in a shop where the work is so specialized that the foreman can follow the work of each man when piece work is undertaken, he can place the man on his own feet and assist him to make the most of his time and to cut out lost movements and other waste in the handling of his tools.

Henry Eckford Rhodes[1] spoke on the general subject of training men for factory work and referred to the methods of early apprenticeship days and his own hardships in securing a mechanical education. He pointed out the greater opportunities afforded at that time because of the greater thoroughness of the boy's training, a thoroughness which the present methods of specialization render impossible. He thought this subject to be of the greatest importance, since lack of efficient men is blocking the growth of American industries, while the non-trade branches including the professions and business occupations, are over-crowded, a condition due to the restrictions which prevent boys from securing apprenticeships in trades. He advocated the establishment of free or partly free industrial schools such as are being successfully operated in Europe, which tend to supplement the education of an ordinary school with training calculated to make the boy a more useful member of society and a larger contributor to the nation's wealth. The colleges and universities and the leading high schools in cities should be equipped with complete mechanical plants and able instructors and the electives should be extended so that greater opportunities might be given for learning trades. The work at the Naval Academy and in our technical colleges proves that it is not impossible to acquire an education and a trade at the same time and he believed that as a result of such a method of procedure many would take up a trade who are now prevented from doing so by present conditions.

[1] Passed Assistant Engineer, U.S.N., Ret.

Prof. Charles F. Park[1] spoke of the work of the Lowell Institute for Industrial Foremen, an evening school maintained by President Lowell under the auspices of the Massachusetts Institute of Technology, described in the discussion of a paper on College and Apprentice Training by J. P. Jackson (Transactions, Vol. 29, p. 507). This school for foremen was not planned for the great mass of so-called working people, but for the minority who are not uneducated, but who have been unable to gain a technical education. It comprises two courses, mechanical and electrical, each extending over two years, and including lectures, recitations, drawing-room exercises and laboratory practice. The courses are conducted by members of the faculty of the Massachusetts Institute of Technology, which has also given the use of its laboratories and class rooms. The students are required to spend two hours at the school three or four evenings a week and as many more hours in home study. There have been about ninety in the first-year class and sixty in the second class.

2 One hundred and eighty-three men have graduated. That the school is making the men more efficient in their regular occupations, and qualifying them for advancement along the lines in which they are working, has been demonstrated by these graduates. This is a strong endorsement of Mr. Alexander's statement that "training will increase their economic value and contentment, and add materially to the productive efficiency of the factory."

3 The paper presents a scheme for training men which in many ways seems ideal. To what extent this may be practically realized under our factory conditions is, in the writer's opinion, open to some question; for industrial activity, competition and numerous manufacturing considerations, the governing conditions for any plan of shop training, would necessarily influence the educational value of the work. The interest of the superintendent and foremen is in the efficiency and output of their departments; questions of instruction are secondary, and under the present scarcity of capable men, it would probably be difficult to find good foremen who would be good teachers. The students themselves, as the author says, must "never forget that they must earn as well as learn in the service of their employer." These conditions seem to be confronting difficulties in the way of thorough training from the educational standpoint.

4 This is not a criticism of shop courses as a whole, for the writer

[1] Director, Lowell School for Industrial Foremen.

believes certain parts of the man's training can be gained as well, if not better, in the factory than in the college or regular school. No course of study can possibly produce a mechanic and engineer, or an electrician, so well fitted that there is nothing left for him to gain from practical experience. His grasp of practical detail and well-balanced judgment will come only after years of service in the factory. But general training in fundamental principles of mathematics and pure applied sciences can best be given in schools which have this training for their aim and not as a secondary purpose. The mechanical industries should not be called upon to give training beyond that directly associated with their processes and methods. These industries are not philanthropic institutions and they cannot be expected to furnish such general training to our young men as we should demand from our public schools and colleges.

George Clinton Ewing[1] said the Westinghouse Electric and Manufacturing Company had a course very similar to that in the General Electric Company described by Mr. Alexander. Delegates were being sent to the various colleges, outlining the company's plan and asking the students to come to them. There are lectures in the evening rather than the day time with various topics for discussion. The students publish the Electric Club Journal, which costs more than is realized from its sale, the deficit being made up by the company. The engineers in the factory give talks and provide papers for the meetings.

Prof. E. F. Miller said that some of the Westinghouse delegates had come to the Massachusetts Institute of Technology and the prospect offered the students seemed a good one. By the company's new arrangement the men are shifted every two months, so that in the course of a year or so they have spent practically two months in every department. The students are to be put in charge of the small testing units up to 500 kw., with a more experienced man over them, and will be called upon to fill vacancies higher up in the company, as soon as these occur.

R. H. Smith.[2] The claims of the scheme outlined by Mr. Alexander are broad, and if true will cause a complete reversal of present

[1] Westinghouse Electric & Mfg. Co., Boston.
[2] Massachusetts Institute of Technology.

methods of education. If mechanical trades and technical subjects such as drawing, mechanism, machine design, pattern-making, machine construction, foundry work, steam, electrical and mechanical engineering, can be taught effectually and rapidly in the shop and factory, then schools and colleges are unnecessary and a needless expense, and our leaders in education have been near-sighted and unwise.

2 For hundreds of years the shop, factory and office provided the only opportunities for a boy to learn a trade or acquire a profession. But under the apprenticeship system the process of learning a trade was slow, illogical, and unsatisfactory to both boy and employer. There was no course, instruction, method or system, to the boy's advancement. The amount of skill and knowledge the boy acquired during his apprenticeship depended upon his own thought and calculation and upon accident, as the teaching results of the shop are small. It was pre-supposed that he would acquire information and skill by observing what went on about him, and his attempts to learn were ventures often disastrous and discouraging.

3 The factory system, with its division of labor, its countless duplication of like parts by means of highly perfected special machinery, where the operations are largely repetitional, was the means of the gradual extinction of the old apprenticeship system, and of the supplanting of the long-trained skilful mechanic by the green hand who can in one or two months be broken in to become an operator or machine specialist, and by repetition becomes expert, but with any change of work or machine is helpless.

4 How does the new apprenticeship system differ from the old? In the old system the boy was under the direction of the foreman, assisted by the journeyman of the department; in the new system he is under the direction of an instructor, assisted by an apprentice. In the old system the boy had quite a variety of work selected from a small shop. In the new system the work is selected from a large manufacturing plant and must be to a great extent work of duplition and repetition, a dulling influence on the boy's mind at that formative age when it is imperative to avoid such influences. Neither the old nor the new systems offer any organized course or systematic instruction. The boy in either case, in large measure, must rediscover elementary facts, as would not be permitted in branches of education other than in the mechanical trades. Under the new system the boy gets a few hours a week of book-learning, but pays dearly for it by having his course unnecessarily lengthened and by

doing more repetitional work, as no company could afford to give him this instruction were it otherwise.

5 Because our forefathers came to the conclusion that learning a trade was slow, illogical, unsystematic, and wasteful of time and money, schools were established and courses organized to supply the deficiencies of shop and factory, and very few would think of returning to the old system.

6 In the evolution of the many systems of teaching, the laboratory or problem method has been the most successful. This is the method in use in our engineering and medical schools, our colleges and universities, and no system in the world has trained so many men so well. It has been employed for more than thirty years at the Massachusetts Institute of Technology. A method is worked out by graded lessons from the simple to the complex, so that with the least expenditure of time a sound, systematic acquirement of information and skill is provided. In the lecture room the instructor, pre-supposing the ignorance of a class of students, begins at the foundation, thus developing the mechanical judgment of the students by making, in advance of practice, a careful study of the problem and its solution.

7 In the laboratories all students have equal opportunities to practice and apply the instruction, not as a venture, but with a clear knowledge of the method of solving, obtaining results many times more effective than can be taught in the shop or factory through constructive and repetitional work. The laboratory method creates enthusiasm and class spirit, tremendous factors in acquiring information and skill, and trains students to think logically and plan intelligently.

8 Mr. Alexander's paper says: "The very fact of this work being a part of the commercial output of the factory automatically insures a high standard of quality and quantity, and eliminates the false notions of these values usually found in purely educational trade schools." When I first came from manufacturing into the profession of teaching, I had this same idea. I thought that schools teaching the mechanical and industrial arts created false notions of accuracy, quality and quantity in the minds of the students. I thought the apprenticeship system of the firm employing thousands of men with which I was formerly connected, gave their apprentices training that could not be improved. Time and experience, however, have proved that it was I who had the false notions and ideas, and that the laboratory or problem method for teaching the principles

of the mechanical and industrial arts as a part of an engineering training, or the essentials of a trade, can never be equalled for rapidity by the apprenticeship system, however perfect, or well or generously managed. The shop and factory have not the facilities for a graded course, nor the necessary teaching knowledge. They cannot properly teach beginnings, while the school cannot teach experience. Each has a field of its own. No word is more misleading in industrial education than the word practical. The laboratory or problem method is the most practical kind of work for the learner and the only true solution of the problem of teaching the mechanical trade rapidly, economically and progressively.

9 This apprenticeship system is undoubtedly well managed and produces as good results as may be obtained or expected from any large shop or modern factory system. Mr. Alexander says: "No course has been laid out for practical work, each apprentice being advanced as fast as is consistent with his individual capacity." While there is no course and, consequently, no systematic instruction, still this system has a field of its own in training its own operators and machine specialists. The essentials of a trade may be taught also by this system provided the apprenticeship course is long enough, say, five to seven years. This will enable the boy to obtain sufficient information and skill to meet changing industrial conditions.

10 While this apprenticeship system will undoubtedly attract many boys who have neither the opportunity nor the means to learn a trade by more rapid methods, it will not find a permanent place in a modern system of education. The American people are striving for the ideal in the field of industrial education and many schemes and plans are being tried out with varying success, and I predict that when this industrial education question is settled it will be along the lines of laboratory or problem methods. This whole subject of industrial education is largely one of the repetition of the factory, and the variety of the school. Repetition is the death of ambition, advancement and development; variety is the life of energy, enthusiasm and progress.

Dickerson G. Baker. Many students of industrial conditions believe that the producing capacity of this country may be limited shortly by the number of men available for properly supervising work. This shortage of competent men is far more noticeable and serious among foremen than among higher executives, and, though rarely admitted, the efficiency of a manufacturin6 plant depends

as much upon a high average ability of foremen and gang bosses as upon executive capacity.

2 In the plant with which I am connected, there have been for years apprentice courses, averaging three years in length, for pattern makers, molders and machinists, and we have a one year course in commercial and designing engineering open to technical graduates only. But we have recently instituted and are giving our principal attention to a class of young men who have been carefully selected as having the proper qualifications to become gang bosses, rate-setters, equipment designers and foremen. Candidates must have had two or more years' machine shop practice and have given evidence of energy, thoroughness and a capacity for analysis.

3 Each student, in this course is first assigned to some machine tool, which he is taught to operate properly, and is given written instructions and a form upon which he records detailed time studies of his work, made along lines developed by Fred. W. Taylor, Past-President of the Society. The importance of realizing the full efficiency of the tool upon the class of work being done is impressed upon the student. Records of time taken for the various steps in the operation being performed, are examined daily by the foreman in charge of the class, and opportunities for improving work and saving time are pointed out. In this way the young man rapidly acquires an appreciation of the value of seconds and of the close study of details.

4 As a student becomes proficient with the operation of one tool he is assigned to others under the same conditions. After a reasonable length of time, he is permitted to make time studies of the work of other operators, and from the records of these studies we are able to make improvements in methods and equipment for the operations observed, and to establish fair and equitable piece-rates, not only reducing our manufacturing cost, but enabling our workmen to earn a considerable increase over their normal day rate. We insist upon fair and straightforward methods in dealing with the workmen in regard to these rates, and there has been practically no trouble in applying them as the student is nearly always able to demonstrate personally that the work can be done in the time assigned.

5 It is noticed that foremen trained in this way tend to proceed in an orderly manner in laying out new work in their departments, When informed as to the number of given parts to be made, they are able to determine the relation which should exist between the amount to be spent for special equipment and the amount to be spent for direct labor on the job.

6 The desirability of the student's having one year of practical experience under actual commercial conditions, between the first and second years of his technical course, brought out by Professor Hollis, is certainly one of the greatest truths before us. I should say further that if we could alternate one year of technical instruction with one year of practical experience, the results would be even better, since repetitive experience has certain great advantages absolutely necessary to the perfection of the competent executive of a manufacturing organization.

Prof. Gardner C. Anthony. I believe the plan of the apprenticeship system to be an excellent one, and a step in the right direction. My criticism relates to the amount and character of the theory to be taught in the proposed course. Problems will probably arise similar to those with which the engineering schools have been struggling in adapting the several courses in shopwork to the curriculum, and we find today a great variety of methods employed for giving this instruction.

2 All classes of shop work should be taught for their educational value, rather than for the information which may be acquired through them. If a course in machine tools for example, is not closely articulated with such subjects as physics, mechanics, mechanism, design, etc., and subjected to the same tests for educational development that are given in other courses, this work had better be relegated to the factory. But because such courses can be made of great pedagogical value by properly articulating them with other courses, they have a proper place in the curriculum of the engineering school.

3 The new form of education under discussion may find a like difficulty in incorporating such subjects as analytical and descriptive geometry, elementary calculus, thermodynamics, etc., into the new curriculum of the factory. This is more likely to occur if an attempt is made to duplicate the courses now given in the colleges, using similar text books and conducting the work in the same manner.

4 A course in descriptive geometry might be given which would not occupy more than one-half the time devoted to that subject in engineering schools; and it should be of a different character more closely allied to the problems to be met in the shop, which necessitates a special text book prepared by those in charge of such a course. This same suggestion would apply to analytical geometry. It will require considerable skill on the part of the instructor to make the element of calculus a live topic in the midst of the pressure of the more practical subjects, although I believe that it can be done.

5 If the subjects can be thus closely related, I believe that the new form of training will be well adapted to a large number of young men who will become capable of filling the better class of positions in engineering establishments.

Prof. Peter Schwamb thought the separation of the instruction department from the shop a wise one, since it brings the student under better supervision and his advance can be made more rapid, if not too much repetitional work is required.

2 While the treatment of the students as individuals in their manual work may advance the better ones more rapidly, the usual effect will be that they obtain more of the instructor's time than is their due, since he will naturally want to instruct where his efforts will make the best showing. The adoption of the class method of instruction will beget a friendly spirit of rivalry among the students and save much valuable time of both instructors and students.

3 The advance of the class should be as rapid as is consistent with the production of good work and the thorough mastering of the operation, the element of expertness being left for future training. The student may be made familiar with the fundamentals, his class-room training being properly correlated to his shop work. After such fundamental training the student may be safely started upon commercial work, with a view of obtaining expertness on the various tools.

4 Mr. Alexander's plan can probably be improved by the adoption of definite courses systematically arranged for the beginners in all departments, such courses covering the fundamental principles and operations in logical order, and it is suggested that such a plan be introduced in the foundry instruction department yet to be equipped. Such courses would also offer a greater attraction to technical graduates, who could obtain through them a much desired practical experience and be brought into close touch with commercial engineering work.

Luther D. Burlingame said there is no substitute for patient and continued practice at a trade and that the apprenticeship system is the most satisfactory means of producing skilled workmen. Its efficiency is greatly increased however by combining with it auxiliary training to supplement the main line of work, such as mathematics, drafting, mechanics, etc., for the machinist apprentice, and varied machine shop work for the draftsman apprentice, these illustrations being typical of the needs in all trades.

2 The value of the shop school is that it makes auxiliary training a necessary part of the course of apprenticeship for which the apprentice is paid and during which he is under full control of his employers. This can be acquired in an evening school, but unless compulsory a large number of those needing this training most would not avail themselves of it.

3 There is a wide field for the employment of different methods in carrying out a system of industrial education in the shop. In the Brown & Sharpe works there are about 150 apprentices coming under some form of auxiliary training. The machinists' apprentices, instead of working part of their time in a machine shop apprentice training room, spend all of their four years of apprenticeship, except for school work, in the regular shop departments. This plan does not require the duplication of machines in another department and it keeps the boys in touch with the more advanced machine operations, so that they can gain experience constantly by observing work going on about them as well as from what they are doing themselves. It brings about contact with the various foremen during the entire period and this mutual acquaintance is helpful in determining the boy's value and, from the apprentice's standpoint, in getting into the spirit of the shop and its personnel. During the time these apprentices are working in the machine shop they are given work in eight or more of the regular departments, thus becoming acquainted with foremen and workmen as well as with methods. No shop should be deterred from establishing an apprenticeship system because it does not feel justified in equipping an apprentice training department where a separate equipment of machines is required.

4 In the Brown & Sharpe works, without the use of text books and without the learning of rules, etc., the problems are presented as they would arise in the shop, except that they are in regular sequence as to subject and difficulty. They are taken up with such reference tables and books at hand as should be in the possession of intelligent mechanics, and the boys are taught how to use such means to solve the problems. They are not taught geometry, algebra, trigonometry, etc., as such, but learn quickly to apply such principles of these sciences as are needed for the problems arising in the shop, and perhaps before knowing these sciences even by name are making practical use of them in their work. Instead of learning certain rules and then applying them, the application comes first showing what the rule must be, or, at least, where in the ordinary

reference books it can be found. Better still, the method of solving a problem is often worked out by the boys based on what they have previously done, and making them to that extent independent both of memorized rules and reference to text books. The whole course is directed toward cultivating the reasoning powers rather than the memory, and gives a chance for the intelligent grammar school graduate to hold his own better than would be expected, in comparison with the ordinary high-school graduate of the same age. The aim is to make skilled machinists, and while this course fits also for foremanships and other lines of advancement, the greatest need of today is for skilled workmen.

5 The speaker also exhibited several blue-prints showing problems to be worked out by the students. These related to linear measurements, fractions and decimal equivalents, screw threads, tapers, gearing, etc., certain data being given from which discussions or other results are to be determined by calculation.

The Author.[1] It was never my intention nor anybody's intention that technological or other schools should be abolished. Let me refer to one or two things. Mr. Smith claims that the repetitive character of our work, so necessary, is absolutely useless in any attempt at training efficient mechanics in these shops. But does he forget that the very same jigs and fixtures that are needed in such large numbers and high efficiency must be made by intelligent mechanics? It does not matter how much repetition work is produced by these jigs. We must have men who can design these jigs and fixtures and can design proper machinery on which these jigs and fixtures can be used.

2 Also a certain amount of repetitive work is not only not bad, but is absolutely necessary for the proper training of a mechanic. The intensity of production which can be taught only through repetitional work must be applied to our growing generation. It is absolutely necessary. You can't teach the intensity of production and all that it means by having a young man make a special tool or a jig or a fixture, because you have no proper, definite measure of the time it should take. But if you let that young man make 50 motor-shafts, you can hold him down not only to absolute commercial accuracy, but to a very fair degree of speed with his own hands and with his machine. How about the many high school graduates who

[1] This discussion was not revised by the author.

cannot or do not want to go to a technological school or to a college? And how about the 75 per cent of the grammar school graduates who never go beyond the public grammar school because they cannot or do not want to enter our industries? All these people, both the high school and the grammar school boys, making almost 100 per cent, must receive mechanical training, if they receive it at all, in the shop, which is the proper place for them to receive it.

3 Should we leave out the class room work because we cannot give it as well as it is given in college? And, let us say, we do not give it as well, because we are not professional teachers. We are professional business men, trying to apply good, sound business principles to education. I think it would be a misfortune to leave it out. Our class room is not so much intended to give definite, concrete knowledge in mechanics. It has a far broader purpose, and the first purpose of all is to give these young men who are growing up and who are going to be our industrial army and our industrial non-commissioned officers, an objective as well as a subjective viewpoint. Our whole labor problem hinges on the fact that our men have only a subjective viewpoint and need an objective one, also; that they cannot see things from the other side as well, but only from their own side. In order to give them that objective viewpoint; in order to develop the character of the men; in order to make them well-intentioned men, good citizens, good working citizens, good workingmen, we have instituted, and I believe every manufacturer should institute, some class room work.

4 We must develop the intelligence at the same time that we are developing the hand. And it is not essential whether the instructor in our class room, pedagogically speaking, toes in or toes out when he is before his class.

TOPICAL DISCUSSION ON RECENT DEVELOPMENTS IN WHEEL TESTING

Dr. C. H. Benjamin

Before proceeding to describe the testing pit recently established at Purdue University for experimental work in bursting various rotating members by centrifugal force, it will perhaps be well to review the progress made in this kind of experimentation since the first work which was reported to the Society in 1898. At that time, the object was to determine the bursting speed of small model flywheels with different types of rims and joints.

2 The first wheels experimented on were 15 in. in diameter. They were rotated by means of a Dow steam turbine, the speed being measured by an electric commutator. The shield used was made of 2-in. pine plank, weighted with heavy castings and timbers. Fig. 1 shows the appearance of the shield after the first explosion. For succeeding experiments, a similar shield of 6 in. by 12 in. white oak was constructed.

3 An increase to 24 in. in the size of the wheels tested resulted in the complete wrecking of this shield, as may be seen by Fig. 2. In all further experiments conducted that year, the shield was made of oak timbers 12 in. square, firmly bolted together and covered with 3-in. oak plank. The speed of the flying fragments is indicated by the fact that some of them cut clean holes through moving belting, similar to those which would be made by bullets. During this year, ten 15-in. and seven 24-in. wheels were broken.

4 Further experiments on 24-in. model wheels were made during the following year and sixteen wheels were broken. The wheels in this series of experiments were enclosed in a cast-steel ring 36 in. in inside diameter, with a rim section 4 in. by 6 in. This was lined

This discussion was presented at St. Louis, March 12, 1910.

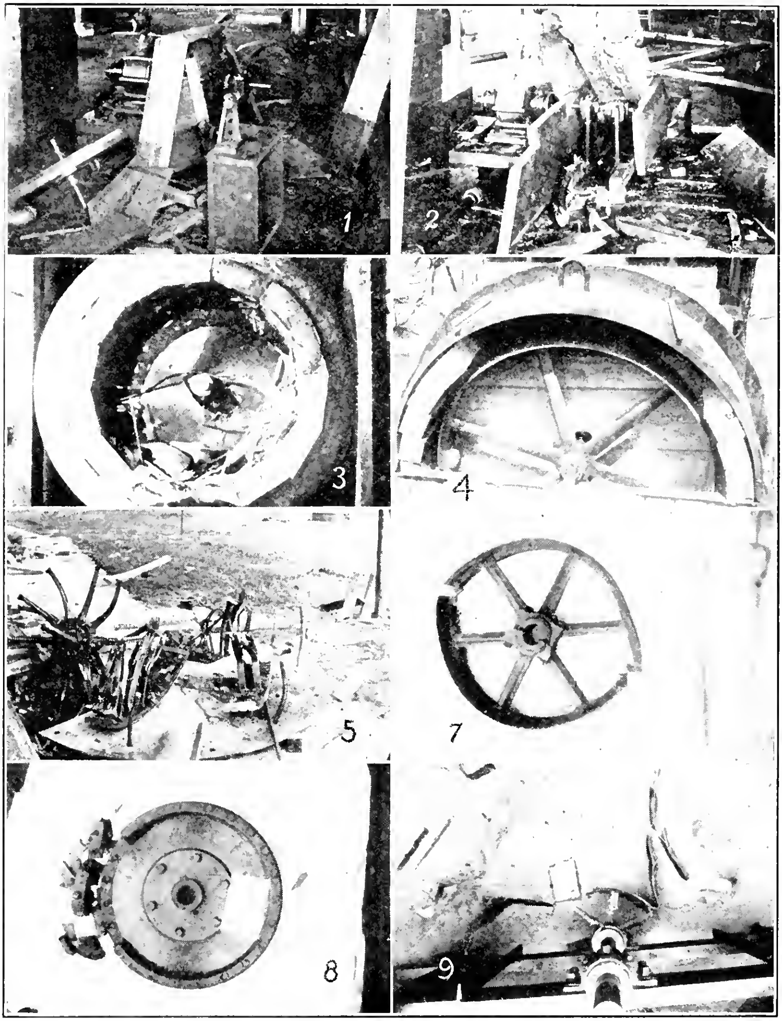


Fig. 1 Shield of 2-in. Pine After Explosion of 15-in. Wheel
Fig. 2 Shield of 6-in. by 12-in. Oak After Explosion of 24-in. Wheel
Fig. 3 Cast-Steel Ring After Explosion of 24-in. Wheel
Fig. 4 Steel Shield for Four 4-ft. Pulleys
Fig. 5 Wreck of 4-ft. Wheel and Shield
Fig. 7 24-in. Steel Pulley Showing Weak Joint
Fig. 8 Paper Pulley
Fig. 9 View Looking Down Into Pit After Explosion of a Steel Pulley

with wooden blocks to absorb the energy of the fragments, and was completely enclosed in oak planking. The same steam turbine was used for driving the pulleys, but a tachometer was used for indicating the speed.

5 The appearance of the casing and wheel after an explosion is shown in Fig. 3. After such an explosion, the wooden blocks would move around in the ring several inches, showing the tangential motion of the fragments. That this apparatus was not entirely safe was demonstrated in one experiment by the escape from the casing of portions of the pulley rim, due to the breaking of the retaining bolts. Although there were numerous spectators in the room, no accident occurred.

6 In this same apparatus fifteen emery wheels of different makes were burst, as reported to the Society in 1903. On account of the greater fragility of the emery wheels, no accident resulted.

7 These experiments were followed in the succeeding year by tests on wooden and steel pulleys 24 in. in diameter. The results of these experiments were published in August 1905 in Machinery. Eight pulleys were tested, including five wood split pulleys, one with steel arms, one all-steel pulley, and one wooden pulley with a solid web which we did not succeed in breaking. A number of pulleys made of paper fiber were tested in the same way, with results not very different from those on wooden pulleys.

8 In 1906 and 1907, a large number of cast-iron discs of various thicknesses and types of hub were exploded in the same apparatus. The results of these experiments, and the conclusions from them, have not yet been published.

9 It seemed desirable to test larger pulleys in the same manner, to see if the peripheral bursting speed would be the same for different sizes of pulleys. A few experiments were made in 1904, on pulleys 4 ft. in diameter. Former experiments had showed that it was hardly safe to burst pulleys of this weight and size inside a building. The apparatus shown in Fig. 4 was built entirely of steel and was 5 ft. in inside diameter. The shield was of rolled boiler plate, $1\frac{1}{4}$ in. thick and having a tensile strength of 65,000 lb. per sq. in. Flat plates $\frac{3}{8}$ in. thick were bolted to the sides so as to enclose completely the wheel tested. Fig. 5 shows the shield after the explosion of the third wheel. The upper half of the casing, weighing about half a ton, was carried 75 ft. in the air and some hundred feet in a horizontal direction.

10 About this time the attention of the writer was called to a vertical shaft used by a German experimenter for bursting emery wheels,

the wheel being mounted at the lower end of the shaft inside a pit. The simplicity and safety of this form of construction are strong points in its favor. The last testing apparatus devised is constructed on this principle and located at Purdue University.

11 Fig. 6, showing a vertical section of the pit and connections, needs little explanation. The weight of the wheel and shaft is supported by a ball and thrust bearing, while rotation is effected by a 10 h.p. motor having a speed which can be varied from 800 to 2400 r.p.m. The pit itself is lined with concrete, but the impact of the fragments is received by a bank of sand. This works admirably to prevent any bruising or smashing of the fragments after the explosion. The speed is taken in the usual way by a tachometer.

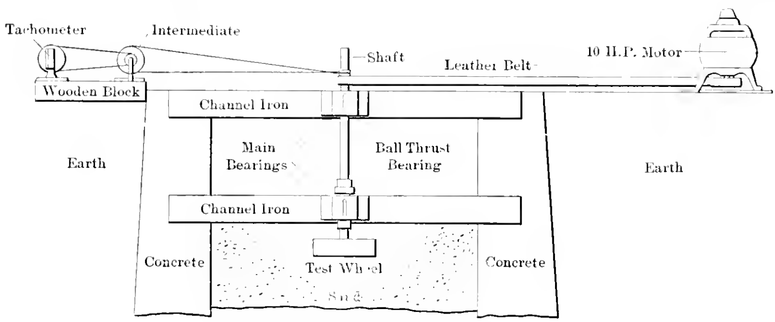


Fig. 6 Flywheel Testing Pit at Purdue University

12 During the winter of 1908–1909, this apparatus was used very successfully[1] in testing the strength of sixteen pulleys, all 24 in. in diameter, with rims from 6 in. to $6\frac{3}{4}$ in. wide. The material used in their construction was wood, cast iron, paper and steel. Some of the rims were solid but most of them were of the usual split pulley type. The linear bursting speed of the solid wooden pulleys was about 275 ft. per sec., or 2600 r.p.m. The linear bursting speed of the split pulleys varied from 220 to 260 ft. per sec., or from 2100 to 2600 r.p.m. The paper pulleys on the other hand, having a solid web, were considerably stronger, averaging about 300 ft. per sec., linear bursting speed, or nearly 2900 r.p.m. Contrary to the usual opinion, the steel wheels are no stronger against bursting than the average wooden pulley. In fact, they are somewhat weaker than a well constructed pulley made of wood. Two wheels tested burst at exactly the same speed, 2240 r.p.m., or 235 ft. per sec.

[1] These experiments were made by Messrs. Biggs and Woodworth, senior students, as a part of their graduating theses.

13 The weakness of this type of pulley is due to the peculiar form of joint fastening, which is bent and broken by the centrifugal pressure. The bursting of the wooden pulleys was due in most cases to the greater density of the balance weights, consisting of slugs of round iron inserted in holes bored in the rim. These caused considerable centrifugal force at the points where they were located. It was evident from the appearance of the broken wheel that some of these weights had forced their way through the rim, thus starting rupture.

14 It is difficult to see how ordinary pulleys with wooden rims can be satisfactorily balanced without weakening. As there is rarely necessity for a linear speed of more than 100 ft. per sec., however, all of the pulleys tested had a factor of safety sufficient for commercial use. This is not true, however, of all pulleys. Two 4-ft. pulleys which were tested burst at speeds of 1100 and 600 r.p.m., respectively, which was considerably less than was expected of them. In the case of the pulley having a solid rim, this was due to the presence inside the rim of a balance weight of $3\frac{1}{2}$ lb. At 1100 r.p.m. the centrifugal force of this balance weight was over 2700 lb. In the same manner, 4-ft. pulley No. 2 was burst by the centrifugal pressure of a flange which weighed with its bolts $7\frac{1}{2}$ lb., and had a centrifugal force at bursting speed of nearly 1700 lb.

15 The effect of a joint flange is particularly disastrous, on account of the weakness of the joint itself to resist bending.

CONCLUSION

16 The bursting speed of most cast-iron pulleys having continuous rims may be put at about 400 ft. per sec., corresponding very nearly to a centrifugal tension of 16,000 lb. per sq. in. A wooden pulley with a continuous web and rim is even stronger than this, since wood is stronger in proportion to its weight than cast iron. A 2-ft. wooden pulley of this description has been run at a speed of 467 ft. per sec. without breaking. The ordinary split pulleys, whether of wood, steel or iron, cannot be relied upon at speeds much over 200 ft. per sec., on account of the weak points which have been mentioned. For experimental high speeds, steel pulleys of a much higher bursting point could undoubtedly be constructed. The poor joint design of the ordinary split steel pulley, such as is used for shafting transmission, renders it unusually weak in this respect.

17 It is proposed to use the testing pit for further experiments along several different lines, one being the testing of various kinds

of grinding wheels, including carborundum as well as the ordinary wet grindstone. The writer also hopes to test out several flywheel joints, on model wheels ranging from 4 ft. to 6 ft. in diameter; also to have some time an opportunity to test some band saw wheels in a similar manner.

DATA AND RESULTS OF EXPERIMENTS MADE IN THE NEW TESTING PIT

No. of Test	Kind of Material in Pulleys	Rim				Weight	Bursting Speed	
		Style	Diameter Inches	Breadth Inches	Depth Inches	Pounds	r. p. m.	Peripheral Speed Ft. per Sec.
1	wood	solid	24	6.25	1.62	29.37	2720	284.7
2	wood	solid	24	6.25	1.62	29.37	2550	266.9
3	wood	2 sections	24	6.5	1.78	29.67	2210	231.8
4	wood	2 sections	24	6.5	1.78	29.67	2110	220.8
5	wood	2 sections	24	6.5	1.78	28.81	2390	251.0
6	wood	2 sections	24	6.5	1.78	28.81	2430	254.3
7	wood	2 sections	24	6.5	1.78	28.81	2360	247
8	wood	2 sections	24	6.5	1.78	28.81	2420	253.3
9	wood	2 sections	24	6.5	1.78	28.81	2570	258.5
10	wood	2 sections	24	6.5	1.78	28.81	2535	244.4
11	cast iron	solid	24	6.0	0.406	70.44	3720	389.4
12	cast iron	solid	24	6.0	0.406	70.44	3380	353.8
13	paper	solid	24	6.0	1.75	77.37	2820	295.2
14	paper	solid	24	6.0	1.75	77.37	2930	306.7
15	steel	2 sections	24	6.75	0.0625	41.75	2240	234.5
16	steel	2 sections	24	6.75	0.0625	41.75	2240	234.5

FURTHER DISCUSSION

Following the introductory discussion by Dr. Benjamin, the question was asked by G. M. Peek if it had been found necessary, after the bursting of a pulley, to renew the driving shaft on which it had been mounted. Dr. Benjamin replied that the shaft was usually sprung by the unbalanced rotation of the pulley after bursting, and had to be replaced by a new one.

2 J. D. McPherson submitted the accompanying sketch (Fig. 1) of a large flywheel with heavy arms split on the centre of an arm. The two parts are dovetailed together and held by prisoners. He explained that this construction avoids the objectionable practice of placing the weight of the joint between the arms.

3 Dr. Benjamin stated that in this way any desired joint efficiency, up to 80 or 90 per cent, could be obtained. There can be no bending action due to centrifugal force and therefore no tendency to open the joint. Most split flywheels are now made with some form of joint over the arms.

4 H. A. Ferguson asked whether any experiments had been made on steel discs such as those used for the cold-sawing of structural steel. They are of open-hearth flange steel and run at a peripheral speed of 22,000 to 26,000 ft. per min. They are frequently replaced b cause of splits on the periphery, but this is apparently due to crystalization caused by the alternate heating and cooling to which they are subjected.

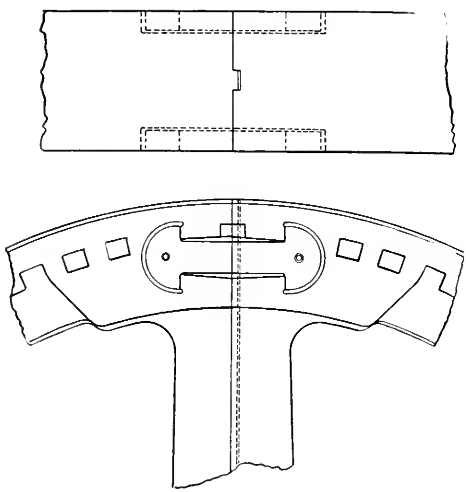


Fig. 1 Large Flywheel with Heavy Arms Split on Center of Arm

5 Dr. Benjamin said that little is known experimentally about the bursting speed of discs, but it is certain that they are stronger than rings, because the web resists the centrifugal tension. Stodola's Steam Turbines, the best theoretical work on the subject, states that the bursting strength of a ring is half that of a solid disc, but the speaker had never believed this statement, although it is theoretically correct. Solid steel discs are probably safe at the speed mentioned, but the practice of punching holes in the discs to balance them is questionable. Even a solid disc might be wrecked by centrifugal force in combination with the severe strains due to the cutting action.

6 Col. E. D. Meier suggested that, since flywheel problems deal with those of 10 or 12 ft. in diameter, and the expense of actual experiments on such wheels would be too great for private institutions, the engineering profession should use its influence to have such experiments made by the Government or at Government expense in private institutions.

7 Prof. H. Wade Hibbard announced that a series of experiments on aeroplane propellers were to be made this spring at the Missouri State University. The propellers are to be of wood, 6 ft. in diameter, and will be run at the speeds used in actual practice, i.e., 600 to 1800 r.p.m. It had been the intention to make the tests in the laboratory, but the experiences of Professor Benjamin with the bursting of flywheels would seem to indicate that this would be dangerous.

8 Dr. Benjamin responded that he would consider any such experiments extremely unsafe unless the apparatus were enclosed with some strong material. No matter what the material, when speeds of from 200 to 400 ft. per sec. are attained, it is vicious. In some of his experiments he found that fragments of wood went through a running belt, leaving holes as clean as a bullet would.

9 Colonel Meier suggested that Professor Hibbard's experiments be extended by testing some propellers to destruction in order to determine the factor of safety of those now being used.

GENERAL NOTES

AMERICAN SOCIETY OF CIVIL ENGINEERS

The annual convention of the American Society of Civil Engineers will be held in Chicago June 21-24, 1910.

At the regular monthly meeting on May 4, two papers were read: Water Supply of the El Paso Southwestern Railway from Carrizozo to Santa Rosa, New Mexico, by J. L. Campbell; and The New York Tunnel Extension of the Pennsylvania Railroad: The site of the Terminal Station, by G. C. Clarke. On May 18, J. C. Meem presented a paper entitled Pressure Resistance and Stability of Earth.

AMERICAN INSTITUTE OF MINING ENGINEERS

On Saturday evening, April 30, the American Institute of Mining Engineers gave a dinner in celebration of the seventieth birthday of Dr. Rossiter W. Raymond, for the last thirty years Secretary of the Institute. Nearly 400 were in attendance.

A gold medal from the Institution of Mining and Metallurgy was presented to Dr. Raymond by R. T. Bayliss, and illuminated parchments which were sent by various foreign engineering bodies were presented by E. G. Spillsburg, Mem. Am. Soc. M. E. Dr. Raymond was also made the recipient of a silver service at the close of the speaking.

Among those who paid tribute to Dr. Raymond were Dr. James Douglas; Dr. Lyman Abbott; George Westinghouse, President Am.Soc.M.Ee.; John Bensel; M. Sorzano de Tajada, of the Société des Ingénieurs Civils de France; Frank Dawson Adams, president of the Canadian Mining Institute; Robert W. Hunt, Past-President, Am.Soc.M.E.; Thomas Commerford Martin; William Lawrence Saunders, Mem.Am.Soc.M.E.

The guests were presented with an illustrated booklet containing scenes from the life of Dr. Raymond.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

The annual convention of the American Insitute of Electrical Engineers will be held June 27-30, at the Waumbek Hotel and cottages at Jefferson, N. H., in the White Mountains. The annual meeting was held at New York May 17. Officers were declared elected as follows: president, Dugald C. Jackson, Mem. Am.Soc.M.E.; vice-presidents, Percy H. Thomas, H. W. Buck, Morgan Brooks, Mem.Am.Soc.M.E.; managers, H. H. Barnes, Jr., C. E. Scribner, W. S. Rugg, R. G. Black; treasurer, Geo. A. Hamilton; secretary, Ralph W. Pope.

On May 5 to 7 a meeting under the auspices of the High Tension Transmission Committee, of which Ralph D. Mershon, Mem.Am.Soc.M.E., is chairman, was held at San Francisco. Elaborate arrangements were made for the entertainment of the members, and professional papers were read as follows: Emergency Generating Stations for Service in Connection with Hydroelectric Transmission Plants under Pacific Coast Conditions, A. M. Hunt, Mem.Am. Soc.M.E.; Hydroelectric Power as Applied to Irrigation, J. C. Hays; The Developed High-Tension Net-Work of a General Power System, Paul M. Downing; Parallel Operation of Three-Phase Generators with their Neutrals interconnected, G. I. Rhodes; Observations of Harmonics in Current and Potential Wave Shapes of Transformers, John J. Frank; Transmission Line Crossings of Railroad Right-of-Way, A. H. Babcock.

NATIONAL ASSOCIATION OF COTTON MANUFACTURERS

The stated annual meeting of the National Association of Cotton Manufacturers was held in the Mechanics Fair Building, Boston, Mass., April 27 and 28, 1910.

An address of welcome was made by Governor Draper of Massachusetts, to which Franklin W. Hobbs, of Boston, responded. Addresses followed by the president, Charles T. Plunkett, Mem.Am.Soc.M.E., Richard C. Maclaurin, President of the Massachusetts Institute of Technology, and Howard Ayres, secretary of the Cotton Goods Export Association. Papers were presented at the sessions of Wednesday afternoon and Thursday on The Progress of the Diesel Engine, Col. E. D. Meier, Mem.Am.Soc.M.E.; The Federal Corporation Tax Law, Walter S. Newhouse; A Substitute for Cotton, James Hope; Superheated Steam and Superheaters, Dr. D. S. Jacobus, Mem.Am.Soc.M.E.; The Electric Drive as a Manufacturing Proposition, Meldon H. Merrill; Choice of Power for Textile Mills, Charles T. Main, Mem.Am.Soc.M.E.; Recent Advances in the Chemistry of Coal Tar Colors, Dr. Hugo Schweitzer; Sizing of Vegetable Fibers, Hermann Seydel; Production-Increasing Methods, Henry L. Gantt, Mem. Am.Soc.M.E.; Distribution of Artificial Light, F. M. Scantlebury; Bibliography of the Cotton Manufacture, Dr. C. J. H. Woodbury, Mem.Am.Soc.M.E.

The following officers were elected: Franklin W. Hobbs, President; George Otis Draper and Edwin Farnham Greene, Vice-Presidents; Albert F. Bemis, R. M. Miller, Jr., Russell B. Lowe, Frederick A. Flather, Mem. Am. Soc. M. E., and Frederick B. Macy, Directors.

LECTURES ON AËRIAL NAVIGATION AT MCGILL UNIVERSITY

The Department of Mechanical Engineering of McGill University has arranged a course of lectures on aërial navigation which will deal with the mechanical principles involved in the construction of the machines, the process of their manufacture, the difficulties of steering and manipulating with the various methods in use to obviate these troubles, and the displacement of air and the theory of gliding. The course will be in charge of Prof. C. M. McKergow.

ADVANCED STUDY OF ELECTRICAL ENGINEERING AT MASSACHUSETTS INSTITUTE OF TECHNOLOGY

The Massachusetts Institute of Technology will this year confer for the first time in its history the degree of Doctor of Engineering. Special attention will be given next year to graduate work. The lectures of Prof. Harold Pender will extend the discussion contained in his advanced lectures of this year on the high-voltage alternating transmission and utilization of power, with a repetition of the general treatment in his lectures of this year on the transmission circuit, and more attention will be given to the conditions arising from the utilization of power. Professor Jackson's lectures for graduate students on the organization and administration of public service companies will next year be directed more to the theory underlying methods of charging for service by public service companies, with particular reference to charges for electric light and power, but with collateral consideration of railroad and tramway charges and charges for gas and the service of other public utilities. Professor Wickenden will originate a course of lectures on illumination, photometry and illuminating engineering, as a part of the optional curriculum for undergraduate and graduate students.

FOREST PRODUCTS LABORATORY AT UNIVERSITY OF WISCONSIN

The Forest Service of the United States and the University of Wisconsin are coöperating in the establishment at Madison, Wis., of a Forest Products Laboratory, which will be prepared to carry on tests of the strength and other properties of timber, the preservative treatment of timber, the saving of wood waste by means of distillation processes, and the fiber of various woods for paper and other purposes. It is proposed to make it the largest and best equipped wood-testing laboratory in the world. The laboratory will be formally opened on June 4, 1910, and representatives of lumber manufacturing and wood-using associations from all parts of the country are expected to attend.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 12th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

026 Young technical graduate with good scholastic record and at least two years practical experience, for position of assistant in the laboratory of an engineering school; salary $1000 for the academic year. Location, Massachusetts.

027 Instructor in the mechanical engineering department of Columbia University, New York; will pay $1000 per year.

028 Manager of well-known company in New York State requires the services of an active, capable, educated and energetic man of good address, tactful in the management of men, familiar with approved systems of commercial and workshop management and costs. Candidate for such position should have thorough practical experience in machine shop and foundry producing heavy machinery for steel works, mills, etc.; large steam and gas engines, general heavy jobbing work and gas producers, also high-class marine and stationary boilers and heavy steel-plate work.

029 Engineer, experienced in the design of hydraulic machinery, pumps and large rolling mills for rolling sheet metal; must be thoroughly competent to make estimates and prepare complete calculations and data for drafting room. Location, Connecticut.

030 Michigan concern engaged in furnishing to several companies on co-operative basis, electric power, live steam, low pressure steam for heating, gas and compressed air, wishes to engage man of executive ability to take entire charge of plant and its operation; he must be qualified to give expert advice on changes or alterations, keep up output and give satisfactory service. Wants thoroughly high-grade competent man.

MEN AVAILABLE

73 University graduate, B.S.M.E., general experience with consulting engineer; five years in engineering and executive positions; building power plant machinery. Past six years with electric railway system in charge of design and construction of modern power house equipment, large units, high and low-pressure turbines, condensers, cooling towers, steam and gas engine plants. Will change on reasonable notice. Eastern location preferred.

74 Junior member, M.E., would like to connect with some consulting engineer, in or around New York. Industrial engineering preferred.

75 Young man desirous of getting away from close application to drafting board; technical graduate; experience in office and construction work as well as drafting, on power and industrial plants, wants commercial work with firm of engineers and contractors or with industrial company.

76 Engineer, 9 years experience in civil engineering, especially hydraulics; 5 years in charge of experimental steam turbine work; desires position as assistant professor of civil or mechanical engineering.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

ABERCROMBIE, James Henderson (1901), Mech. Supt., Clark Thread Co., Clark and Ogden Sts., Newark, N. J.

ALBERGER, Louis R. (1889), Pres., Alberger Condenser Co., 140 Cedar St., New York, N. Y.

ATKINS, David Fowler (1907), Supv. Architects Office, Treasury Dept., Washington, D. C.

BIBBINS, James Rowland (1904; 1909), Engr. with Bion J. Arnold, 154 Nassau St., New York, N. Y.

BILLINGS, William Richardson (1906), Secy. and Treas., Alberger Condenser Co., and Alberger Pump Co., 140 Cedar St., New York, and 151 Columbia Hgts., Brooklyn, N. Y.

BIXBY, William P. (Junior, 1908), Mech. Dept., Erie R. R. Co., 50 Church St., New York, N. Y.

CAMPBELL, Gordon M. (1906), Genl. Elec. Co., Turbine Dept., West Lynn, Mass.

CASH, Arthur Wise (1899), Charge Regulating Valve and Engrg. Dept., H. Mueller Mfg. Co., Decatur, Ill.

CHAMBERS, Norman C. (Junior, 1905), Sales Dept., Niles-Bement-Pond Co., 111 Broadway, New York, N. Y., and *for mail*, care F. H. Bagge, Calle San Martin, 121, Buenos Aires, Argentine Republic, South America.

CREELMAN, Frank (1894), 447 W. 23d St., New York, and *for mail*, Hotel Cunningham, Sandy Hill, N. Y.

DAUGHERTY, Samuel Bovard (1905), Ch. Draftsman, Gas Eng. Dept., Snow Steam Pump Wks., and *for mail*, 129 N. Norwood Ave., Buffalo, N. Y.

DECKER, Edward P. (1906), E. P. Decker & Co., 80 Griswold St., and 79 Pingree Ave., Detroit, Mich.

ELLICOTT, Edw. Beach (1903), Elec. Engr., Sanitary Dist. of Chicago, 1500 Am. Trust Bldg., and *for mail*, 6229 Winthrop Ave., Chicago, Ill.

ESTES, William Wood (1891; 1904), Designer, Genl. Fire Extinguisher Co., and *for mail*, 245 Waterman St., East Side Sta., Providence, R. I.

FRANCIS, W. H. (1884), Union League, Broad and Sansom Sts., Philadelphia, Pa.

FRITZ, Aime L. G. (Junior, 1907), Ch. Draftsman, Hartford Suspension Co., 150 Bay St., Jersey City, N. J., and *for mail*, 99 Elmwood St., Woodhaven, L. I., N. Y.

GATES, Philetus W. (1902), Vice-President, 1906-1908; Pres., Hanna Engrg. Wks., 2059 Elston Ave., Chicago, Ill.

GIBBS, Geo. (1890), Ch. Engr. Elec. Traction and Terminal Sta. Constr., Pa. Tunnel & Terminal R. R. Co., Ch. Engr. Elec. Traction, West Jersey & Seashore R. R. Co., L. I. R. R. Co., 32d St. and Seventh Ave., New York, N. Y.

HAMERSTADT, William Diehl (Junior, 1907), Engr., Rockwood Mfg. Co., and *for mail*, 1608 Central Ave., Indianapolis, Ind.

HARTNESS, R. B. (Associate, 1903), 3042 Foster St., Los Angeles, Cal.

HECK, Robert C. H. (1906), Prof. Mech. Engrg., Rutgers College, and *for mail*, 35 College Ave., New Brunswick, N. J.

HEIKEL, Daniel August (1899), Life Member; M. E., Rm. 745, Oliver Bldg., Pittsburg, Pa.

HILL, E. Rowland (1907), Asst. to Ch. Engr., Elec. Traction, Pa. Tunnel & Terminal R. R., 32d St. and Seventh Ave., New York, N. Y., and 76 Watson Ave., East Orange, N. J.

HUNTER, John A. (1909), Steam Engr., Am. Sheet & Tin Plate Co., Frick Bldg., Pittsburg, and Dickson Ave., Ben Avon, Pa.

HUTTON, Mancius S. (Junior, 1908), Junior Salesman, Am. Radiator Co., Bundy Dept., 129 Federal St., and *for mail*, 172 Huntington Ave., Boston, Mass.

HVID, Rasmus M. (1907; Associate, 1909), 29 Market St., Bethlehem, Pa.

KEITH, Robert R. (Junior, 1904), Asst. Genl. Supt., Light Fuel Oil Pump Co., and *for mail*, 687 Farwell Ave., Milwaukee, Wis.

KNIGHT, Hervey S. (Associate, 1898), Pat. Lawyer and Expt., 726 Ninth St., N. W., and 30 Piney Branch Rd., Washington, D. C.

LANE, Henry Marquette (1900), Editor, Castings and Wood Craft, Caxton Bldg., and *for mail*, 10613 Greenlawn Ave., Cleveland, O.

LARKIN, A. C. (1895; 1905), Babcock & Wilcox, Ltd., College St., St. Henry, Montreal, Canada.

LEWIS, John Ernest (Junior, 1909), Paonia, Colo.

LILLIBRIDGE, Ray D. (Associate, 1907), 195 Broadway, and P. O. Box 824, New York, N. Y.

McARTHUR, Arthur Royal (1906), Resident Engr., Am. Sheet & Tin Plate Co., and *for mail*, 674 Harrison St., Gary, Ind.

MARBURG, Louis Chas. (1909), 1777 Broadway, New York, N. Y.

MORLEY, Ralph (Junior, 1906), Mech. Engr., Transmission Dept., The Fairbanks Co., New York, N. Y., and *for mail*, 153 Delavan Ave., Newark, N. J.

NEWCOMB, Chas. L., Jr. (Associate, 1908), Denver Rock Drill & Mchy. Co., 18th and Blake Sts., Denver, Colo.

PARSONS, W. Everett (1899), Cons. Engr., 12 Bridge St., New York, and *for mail*, 10 Rich Ave., Mt. Vernon, N. Y.

PERRY, Samuel B. (Junior, 1895), Ins. Engr., 68 William St., New York, and Hollis, L. I., N.Y.

PHELPS, Charles C. (Junior, 1909), Editor, Steam, 2108 West St. Bldg., New York, N. Y.

POSEY, James (Junior, 1907), Cons. Engr., Painter & Posey, Cons. Engrs., 324 N. Charles St., Baltimore, Md.

RAY, Frederick (Junior, 1903), Ch. Engr., Alberger Pump Co., 140 Cedar St., New York, N. Y., and 19 Wilcox Place, East Orange, N. J.

REEDER, Nathaniel S., Jr. (1902; 1907), West Steel Car & Fdy. Co., 1470 Old Colony Bldg., Chicago, Ill.

ROGERS, Robert W. (Junior, 1908), Erie R. R., and *for mail*, 216 Walnut St., Meadville, Pa.

SALTZMAN, Auguste L. (1908), M.E., Asst. Ch. Engr., Edison Cos., Edison Laboratory, Orange, and *for mail*, 41 Watson Ave., East Orange, N. J.

SAMPSON, Chas.C. (1909), M. E., Supt. Constr., 5-8 Blowing Eng., Illinois Steel Co., South Chicago, and *for mail*, 7318 Champlain Ave., Chicago, Ill.

SANDO, Will J. (1899), Manager, 1908-1911; 430 Kane Pl., Milwaukee, Wis.

SCOTT, Walter G. (Junior, 1909), Cyclone Drill Co., Orville, O.

SEYMOUR, Dudley S. (1905), Supt., Union Spec. Mch. Co., 300 W. Kinzie St., Chicago, and *for mail*, 228 N. Elmwood Ave., Oak Park, Ill.

SMITH, Harry Ernest (1897), Chem. and Engr. of Tests, L. S. & M. S. Ry., Collinwood, and *for mail*, 36 Beersford Place, East Cleveland, O.

SMITH, J. Waldo (1896), Ch. Engr., Board of Water Supply, City of N. Y., 165 Broadway, and 136 Madison Ave., New York, N. Y.

STEENSTRUP, Peter Severin (1906), Box 1843, Seattle, Wash.

SYMONDS, George P. (1908), Chief Engrg. Dept., Alberger Condenser Co., 140 Cedar St., New York, N. Y.

TADDIKEN, J. F., Jr. (Junior, 1907), Am. Beet Sugar Co., Chino, Cal.

TERWILLIGER, Harry L. (Associate, 1901), Sales Mgr., Harron, Rickard & McCone, 139-149 Townsend St., San Francisco, and *for mail*, 1121 Emerson St., Palo Alto, Cal.

ULRICH, Max Julius (1906), Ch. Draftsman, Alberger Condenser Co., 140 Cedar St., New York, N. Y.

WADSWORTH, Frank L. O. (1903), Cons. Engr., 1347-1348 Oliver Bldg., and Duquesne Club, Pittsburg, Pa.

WESTERFIELD, George Sumner (Junior, 1903), Mgr. and Dist. Mgr., Hooven, Owens, Rentschler Co., Warren Webster & Co., B. F. Sturtevant Co., 326-329 Hennen Bldg., and 1320 Eleonore St., New Orleans, La.

WHITE, James A. (Junior, 1900), Genl. Elec. Co., and *for mail*, 19 Red Rock St., Lynn, Mass.

WHITEFORD, James F. (1908), Santa Fe Shops, Topeka, Kan.

WILLIAMSON, Leroy A. (Associate, 1902), Board of Trade Bldg., 131 State St., Boston, Mass.

WILSON, Wm. R. (Junior, 1899), Alberger Condenser Co., 140 Cedar St., New York, and *for mail*, 224 Palisade Ave., Yonkers, N. Y.

WINSHIP, James G. (1891), Internatl. Steam Pump Co., 115 Broadway, New York, and *for mail*, 209 Ocean Ave., Brooklyn, N. Y.

NEW MEMBERS

HODGE, Wm. W. (Junior, 1909), Field Engr., Dodge & Day, Lewiston, Pa.

DEATHS

BARY, Mark, December 1909.

BLOOMBERG, Jonas H.

EMERSON, Ralph Waldo, April 13, 1910.

PARSONS, William N., April 24, 1910.

PLUMMER, Frank J., April 15, 1910.

SPARROW, Ernest P., April 18, 1910.

GAS POWER SECTION

CHANGES OF ADDRESS

BIBBINS, James Rowland (1908), Mem.Am.Soc.M.E.
BIGELOW, Lucius S. (Affiliate, 1910), Pres., Light Pub. Co.,Pres.,Periodical's Pub. Co., 125 S. Main St., Willimantic, Conn.
HILLEBRAND, Herman (Affiliate, 1909), 638 W. Broad St., Bethlehem, Pa.
HOPCROFT, Ernest Bigly (Affiliate, 1908), L. W. Hall & Co., 50 Congress St., Boston, Mass.
MORLEY, Ralph (1908), Mem. Am.Soc.M.E.
RALSTON, Louis C. (Affiliate, 1909), R. F. D. 21, Box 41 A, San Jose, Cal.
SAMPSON, Chas. C. (1909), Mem.Am.Soc.M.E.

NEW MEMBERS

RIEPPEL, Paul (Affiliate, 1910), Blohm & Voss, Hamburg, Germany.

DEATHS

SPARROW, Ernest P., April 18, 1910.

STUDENT BRANCHES

CHANGES OF ADDRESS

GOLDSMITH, W. M. (Student, 1909), Greenwood Court, Greenwood Ave., Avondale, Cincinnati, O.
HESS, Harry L. (Student, 1909), Marysville, Cal.
LEVY, M. S. (Student, 1909), Metropole Hotel, Chicago, Ill.
MUDD, John P. (Student, 1909), 229 Zeralda St., Philadelphia, Pa.
SHULTS, L. J. (Student, 1909), 1820 S. Sawyer Ave., Chicago, Ill.
THOMAS, W. E. (Student, 1909), 4028 Sheridan Rd., Chicago, Ill.
WATSON, R. D. (Student, 1910), 237 Langdon St., Madison, Wis.

NEW MEMBERS

STEVENS INSTITUTE OF TECHNOLOGY

POLHEMUS, D. A. (Student, 1910), Stevens Inst. of Tech., Hoboken, N. J.

UNIVERSITY OF MAINE

BLAISDELL, A. H. (Student, 1910), 57 Fifth Ave., Bangor, Me.
COLE, R. F. (Student, 1910), Phi Beta Kappa House, Orono, Me.
CUMMINGS, C. G. (Student, 1910), Delta Tau Delta House, Orono, Me.
DANFORTH, H. N. (Student, 1910), Alpha Tau Omega House, Orono, Me.
HAMMOND, A. C. (Student, 1910), Main St., Orono, Me.
HARDY, S. J. (Student, 1910), Delta Tau Delta House, Orono, Me.
JOHNSON, C. A. (Student, 1910), Orono, Me.
LITTLEFIELD, P. H. (Student, 1910), Orono, Me.
MERRIAM, F. E. (Student, 1910), Orono, Me.
SCALES, E. M. (Student, 1910), Theta Epsilon House, Orono, Me.
SIMONTON, P. D. (Student, 1910), Orono, Me.

UNIVERSITY OF MISSOURI

EDGAR, O. N. (Student, 1910), 605 S. Fourth St., Columbia, Mo.
KENNEDY, F. T. (Student, 1910), Benton Hall, Columbia, Mo.
OLSEN, C. A. (Student, 1910), 411 S. Fifth St., Columbia, Mo.
PHILLIPS, E. C. (Student, 1910), 505 Conley Ave., Columbia, Mo.
PRICE, H. W. (Student, 1910), Lowry Hall, Columbia, Mo
SEXTON, C. E. (Student, 1910), 605 S. Fourth St., Columbia, Mo.
SHARP, H. N. (Student, 1910), 311 Waugh St.,Columbia, Mo.
STEED, A. (Student, 1910), Benton Hall, Columbia, Mo.
THACHER, F. B. (Student, 1910), Y. M. C.A. Bldg., Columbia, Mo.
WEAVER, H. E. (Student, 1910). 803 Virginia Ave., Columbia, Mo.
WESTCOTT, A. L. (Student, 1910), 1102 Windsor St., Columbia, Mo.

UNIVERSITY OF WISCONSIN

FALK, G. S. (Student, 1910), 627 Lake St., Madison, Wis

COMING MEETINGS

May–June

Advance notices of annual and semi-annual meetings of engineering societies are regularly published under this heading and secretaries or members of societies whose meetings are of interest to engineers are invited to send such notices for publication. They should be in the editor's hands by the 18th of the month preceding the meeting. When the titles of papers read at monthly meetings are furnished they will also be published.

AMERICAN EXPOSITION IN BERLIN

June 1–Aug. 31. American Manager, Max Vieweger, 50 Church St., New York.

AMERICAN BRASS FOUNDERS' ASSOCIATION

June 6–10, Detroit, Mich. Papers: Costs and Cost Systems, C. R. Stevenson; Analysis for Lead in Brass Alloys, C. P. Karr; Coöperatjve Course in Metallurgy, J. J. Porter; Electric Furnaces for Melting Non-Ferrous Alloys, A. L. Marsh; Fluxes as Applied to the Brass Foundry, I. S. Sperry; Electric Power as Applied to Melting, J. W. Richards, Mem. Am. Soc. M. E. Secy., W. M. Corse, Lumen Bearing Co., Buffalo, N. Y.

AMERICAN FOUNDRYMEN'S ASSOCIATION

June 6–10, Detroit, Mich. Secy. of general committee, A. Preston Henry, Standard Pattern Works.

ASSOCIATION OF CAR-LIGHTING ENGINEERS

June 7–8, semi-annual convention, Buffalo, N. Y. Secy., Geo. B. Colegrave, care of Central Railway, Chicago.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

June 22–24, summer meeting, Niagara Falls, N. Y. Secy., J. C. Olsen, Polytechnic Inst., Brooklyn.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

June 27–28, Annual Convention, Waumbek Hotel, Jefferson, N. H. Secy., R. W. Pope, 33 W. 39th St.

AMERICAN PORTLAND CEMENT MANUFACTURERS

June, Kansas City, Kans. Secy., P. H. Wilson, Land Title Bldg., Philadelphia, Pa.

AMERICAN RAILWAY ACCOUNTING OFFICERS

June 29, Colorado Springs, Colo. Secy., C. G. Phillips, 143 Dearborn St., Chicago.

AMERICAN RAILWAY MASTER MECHANICS ASSOCIATION

June 20–22, Atlantic City, N. J. Secy., J. W. Taylor, 390 Old Colony Bldg., Chicago.

AMERICAN SOCIETY OF CIVIL ENGINEERS

June 1, 220 W. 57th St., New York. Papers: The New York Tunnel Extension of the Pennsylvania Railroad, B. H. M. Hewett; The North River Tunnels, W. L. Brown. June 21–24, Annual Convention, Chicago, Ill. Secy., C. W. Hunt, New York.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
May 27, St. Louis, with coöperation of Engineers Club of St. Louis. May 31–June 3, Spring Meeting, Atlantic City, N. J. July 26–29, meeting with Institution of Mechanical Engineers, in Birmingham and London, England. Secy., Calvin W. Rice, 29 W. 39th St., New York.

AMERICAN SOCIETY FOR TESTING MATERIALS
June 28–July 2, annual meeting, Atlantic City, N. J. Secy., Edgar Marburg, University of Pennsylvania, Philadelphia.

CANADIAN ELECTRICAL ASSOCIATION
July 6–8, annual convention, Royal Muskoka, Lake Rosseau. Secy., T. S. Young, Confederation Life Bldg., Toronto, Ont.

CANADIAN GAS ASSOCIATION
June 9–11, annual convention, Alexandra Rink, Hamilton, Ont. Secy., A. W. Moore, Woodstock, Ont.

CLEVELAND ENGINEERING SOCIETY
June 14, annual meeting, 711 Caxton Bldg. Secy., J. C. Beardsley.

ENGINEERS' CLUB OF BALTIMORE
June 4, annual meeting. Secy., R. K. Compton, City Hall.

ENGINEERS SOCIETY OF MILWAUKEE
June 8, annual meeting, Builders Club. Secy., W. F. Martin, 456 Broadway.

ENGINEERS SOCIETY OF PENNSYLVANIA
June 7, annual meeting, Gilbert Bldg., Harrisburg. Secy., E. R. Dasher, P. O. Box 704.

FREIGHT CLAIM ASSOCIATION
June 15, Los Angeles, Cal. Secy., W. P. Taylor, Richmond, Va.

INTERNATIONAL CONGRESS OF INVENTORS
June 13–18, Rochester, N. Y.

INTERNATIONAL CONGRESS OF MINING, METALLURGY, APPLIED MECHANICS AND PRACTICAL GEOLOGY
Last week in June, Düsseldorf, Prussia. Secy., Dr. E. Schrödter, Jacobstrasse 315.

IOWA DISTRICT GAS ASSOCIATION
June 15–17, annual meeting, Sioux City. Secy., G. I. Vincent, Des Moines.

MANUFACTURERS' SUPPLY ASSOCIATION
June 6–10, exhibit, Detroit, Mich. Secy., C. E. Hoyt, Lewis Institute, Chicago.

MASTER CAR BUILDERS ASSOCIATION
June 15–17, Atlantic City, N. J. Secy., J. W. Taylor, 390 Old Colony Bldg., Chicago.

NATIONAL DISTRICT HEATING ASSOCIATION
June 1–3, annual meeting, Toledo, O. Secy., D. C. Gaskill, Greenville, O.

NATIONAL ELECTRIC CONTRACTORS' ASSOCIATION
July 20, annual meeting, Atlantic City, N. J. Secy., W. H. Morton, Martin Bldg., Utica, N. Y.

NATIONAL ELECTRIC TRADES ASSOCIATION
June, San Francisco, Cal. Secy., F. B. Vose, 1343 Marquette Bldg., Chicago.

NATIONAL GAS AND GASOLINE ENGINE TRADES ASSOCIATION

June 13-16, semi-annual meeting, Hotel Sinton, Cincinnati, O. Subjects for discussion: Carbureters, Geo. M. Schebler; Ignition in Gas and Gasoline Engines, Carl Pfanstiehl; Gas Producers, L. F. Burger; Present and Future Opportunities in the South for the Gas Engine Boiler, W. R. C. Smith; How to Illustrate and Describe Mechanical Installations, O. Monnett; Heavy Hitting in the Advertisers' League, Ren Mulford, Jr.; Some Association Experiences, F. J. Alvin; Dry Batteries, H. S. Green; The Gas Engine Field in Mexico, G. W. Hall; Large Gas Engines, J. D. Lyon. Secy., Albert Stritmatter.

NATIONAL SOCIETY FOR PROMOTION ENGINEERING EDUCATION

June 23-25, annual meeting, Madison, Wis. Papers on Technical Education Abroad; Inspection Trips for Technical Students, Efficiency in Technical Education. Secy., Prof. H. H. Norris, Cornell University, Ithaca, N. Y.

NEW ENGLAND WATERWORKS ASSOCIATION

June, Providence, R. I. September 14-16, annual convention, Rochester N. Y. Secy., Willard Kent, Narragansett Pier, R. I.

PROVIDENCE ASSOCIATION OF MECHANICAL ENGINEERS

June 28, annual meeting. Secy., T. M. Phetteplace, Mem.Am.Soc.M.E., 48 Snow St.

RAILWAY SIGNAL ASSOCIATION

June 14, 29 W. 39th St., New York, 9.30 a.m. Secy., C. C. Rosenberg, Bethlehem, Pa.

RENSSELAER SOCIETY OF ENGINEERS

June, annual meeting, Rensselaer Polytechnic Inst., 257 Broadway, Troy, N. Y. Secy., R. S. Furber.

TELEPHONE SOCIETY OF NEW YORK

June 21, annual meeting, 29 W. 39th St. Secy., T. H. Woolhouse.

TRANSPORTATION AND CAR ACCOUNTING OFFICERS

June 28. Secy., G. P. Conard, 24 Park Pl., New York.

MEETINGS IN THE ENGINEERING SOCIETIES BUILDING

Date	Society	Secretary	Time
June			
1	Wireless Institute	S. L. Williams	7.30
2	Blue Room Engineering Society	W. D. Sprague	8.00
3	Western Union Electrical Society	H. C. Northen	7.00
4	Amer. Soc. Hun. Engrs and Archts	E. L. Mandel	8.30
9	Illuminating Engineering Society	P. S. Millar	8.15
10	Western Union Electrical Society	H. C. Northen	7.00
			a.m.
14	Railway Signal Association	C. C. Rosenberg	9.30
			p.m.
17	Western Union Electrical Society	H. C. Northen	7.00
21	New York Telephone Society	T. H. Lawrence	8.00
24	Western Union Electrical Society	H. C. Northen	7.00
July			
7	Blue Room Engineering Society	W. D. Sprague	8.00

OFFICERS AND COUNCIL

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George Westinghouse .... Pittsburg, Pa.

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Terms expire at Annual Meeting of 1910

Charles Whiting Baker .... New York
W. F. M. Goss .... Urbana, Ill.
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Terms expire at Annual Meeting of 1911

PAST PRESIDENTS

Members of the Council for 1910

John R. Freeman .... Providence, R. I.
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M. L. Holman .... St. Louis, Mo.
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MANAGERS

Wm. L. Abbott .... Chicago, Ill.
Alex. C. Humphreys .... New York
Henry G. Stott .... New York

Terms expire at Annual Meeting of 1910

H. L. Gantt .... Pawtucket, R. I.
I. E. Moultrop .... Boston, Mass.
W. J. Sando .... Milwaukee, Wis.

Terms expire at Annual Meeting of 1911

J. Sellers Bancroft .... Philadelphia, Pa.
James Hartness .... Springfield, Vt.
H. G. Reist .... Schenectady, N. Y.

Terms expire at Annual Meeting of 1912

TREASURER

William H. Wiley .... New York

CHAIRMAN OF THE FINANCE COMMITTEE

Arthur M. Waitt .... New York

HONORARY SECRETARY

F. R. Hutton .... New York

SECRETARY

Calvin W. Rice .... 29 West 39th Street, New York

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H. L. Gantt
F. M. Whyte

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FINANCE

Arthur M. Waitt (5), *Chairman*
Robert M. Dixon (3), *Vice-Chairman*
Edward F. Schnuck (1)
Geo. J. Roberts (2)
Waldo H. Marshall (4)

HOUSE

William Carter Dickerman (1) *Chairman*
Francis Blossom (3)
Bernard V. Swenson (2)
Edward Van Winkle (4)
H. R. Cobleigh (5)

LIBRARY

John W. Lieb, Jr. (3), *Chairman*
Leonard Waldo (2)
Ambrose Swasey (1)
Chas. L. Clarke (4)
Alfred Noble (5)

MEETINGS

Willis E. Hall (5), *Chairman*
L. R. Pomeroy (2)
Wm. H. Bryan (1)
Chas. E. Lucke (3)
H. de B. Parsons (4)

MEMBERSHIP

Charles R. Richards (1) *Chairman*
George J. Foran (3)
Francis H. Stillman (2)
Hosea Webster (4)
Theo. Stebbins (5)

PUBLICATION

D. S. Jacobus (1) *Chairman*
Fred R. Low (3)
H. F. J. Porter (2)
Geo. I. Rockwood (4)
Geo. M. Basford (5)

RESEARCH

W. F. M. Goss (4), *Chairman*
R. H. Rice (2)
R. C. Carpenter (1)
Ralph D. Mershon (3)
Jas. Christie (5)

Note—Numbers in parentheses indicate number of years the member is yet to serve.

SPECIAL COMMITTEES
1910

On a Standard Tonnage Basis for Refrigeration

D. S. Jacobus
A. P. Trautwein
G. T. Voorhees
Philip De C. Ball
E. F. Miller

On Society History

John E. Sweet
H. H Suplee
Chas. Wallace Hunt

On Constitution and By-Laws

Chas. Wallace Hunt, *Chairman*
G. M. Basford
F. R. Hutton
D. S. Jacobus
Jesse M. Smith

On Conservation of Natural Resources

Geo. F. Swain, *Chairman*
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L. D. Burlingame
M. L. Holman
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On International Standard for Pipe Threads

E. M. Herr, *Chairman*
William J. Baldwin
Geo. M. Bond
Stanley G. Flagg, Jr.

On Standards for Involute Gears

Wilfred Lewis, *Chairman*
Hugo Bilgram
E. R. Fellows
C. R. Gabriel
Gaetano Lanza

On Power Tests

D. S. Jacobus, *Chairman*
Edward T. Adams
George H. Barrus
L. P. Breckenridge
William Kent
Charles E. Lucke
Edward F. Miller
Arthur West
Albert C. Wood

On Student Branches

F. R. Hutton, Honorary Secretary

On Meetings of the Society in Boston

Ira N. Hollis, *Chairman*
Edward F. Miller
I. E. Moultrop, *Secretary*
J. H. Libbey
Charles T. Main

On Meetings of the Society in St. Louis

Wm. H. Bryan, *Chairman*
R. H. Tait, *Vice-Chairman*
Earnest L. Ohle, *Secretary*
M. L. Holman
Fred E. Bausch

On Arrangements for Joint Meeting in England

Ambrose Swasey, *Chairman*
Geo. M. Brill
John R. Freeman
W. F. M. Goss
George Westinghouse
Chas. Whiting Baker, *Vice-Chairman*
F. R. Hutton
Willis E. Hall
Calvin W. Rice
Wm. H. Wiley

SOCIETY REPRESENTATIVES

1910

On John Fritz Medal

AMBROSE SWASEY (1)
CHAS. WALLACE HUNT (3)
F. R. HUTTON (2)
HENRY R. TOWNE (4)

On Board of Trustees United Engineering Societies Building

F. R. HUTTON (1)
FRED J. MILLER (2)
JESSE M. SMITH (3)

On Library Conference Committee

J. W. LIEB, JR., CHAIRMAN OF THE LIBRARY COMMITTEE, AM. SOC. M. E.

On National Fire Protection Association

JOHN R. FREEMAN
IRA H. WOOLSON

On Joint Committee on Engineering Education

ALEX. C. HUMPHREYS
F. W. TAYLOR

On Advisory Board National Conservation Commission

GEO. F. SWAIN
JOHN R. FREEMAN
CHAS. T. MAIN

On Council of American Association for the Advancement of Science

ALEX. C. HUMPHREYS
FRED J. MILLER

NOTE—Numbers in parentheses indicate number of years the member is yet to serve.

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1909-1910

CHAIRMAN
J. R. Bibbins

SECRETARY
Geo. A. Orrok

GAS POWER EXECUTIVE COMMITTEE

F. H. Stillman (1), *Chairman*
G. I. Rockwood (2)
F. R. Hutton (3)
H. H. Suplee (4)
F. R. Low (5)

GAS POWER MEMBERSHIP COMMITTEE

H. R. Cobleigh, *Chairman*
H. V. O. Coes
A. E. Johnson
F. S. King
A. F. Stillman
G. M. S. Tait
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OFFICERS OF STUDENT BRANCHES

INSTITUTION	BRANCH AUTHORIZED BY COUNCIL	HONORARY CHAIRMAN	PRESIDENT	CORRESPONDING SECRETARY
	1908			
Stevens Inst. of Tech., Hoboken, N. J.	December 4	Alex. C. Humphreys	H. H. Haynes	R. H. Upson
Cornell University, Ithaca, N. Y.	December 4	R. C. Carpenter	C. C. Allen	C. F. Hirschfeld
	1909			
Armour Inst. of Tech., Chicago, Ill.	March 9	G. F. Gebhardt	F. E. Wernick	W. E. Thomas
Leland Stanford, Jr. University, Palo Alto, Cal.	March 9	W. F. Durand	A. F. Meston	J. B. Bubb
Polytechnic Institute, Brooklyn, N. Y.	March 9	W. D. Ennis	J. S. Kerins	Percy Gianella
State Agri. College. Corvallis, Ore.	March 9	Thos. M. Gardner	C. L. Knopf	S. H. Graf
Purdue University, Lafayette, Ind.	March 9	L. V. Ludy	E. W. Templin	H. A. Houston
Univ. of Kansas, Lawrence, Kan.	March 9	P. F. Walker	C. E. Johnson	C. A. Swiggett
New York Univ., New York	November 9	C. E. Houghton	Harry Anderson	Andrew Hamilton
Univ. of Illinois, Urbana, Ill.	November 9	W. F. M. Goss	B. L. Keown	C. S. Huntington
Penna. State College, State College, Pa.	November 9	J. P. Jackson	G. B. Wharen	G. W. Jacobs
Columbia University, New York	November 9	Chas. E. Lucke	F. R. Davis	H. B. Jenkins
Mass. Inst. of Tech., Boston, Mass.	November 9	Gaetano Lanza	Morril Mackenzie	Foster Russell
Univ. of Cincinnati, Cincinnati, O.	November 9	J. T. Faig	W. H. Montgomery	P. G. Haines
Univ. of Wisconsin, Madison, Wis.	November 9	C. C. Thomas	John S. Langwill	Karl L. Kraatz
Univ. of Missouri, Columbia. Mo.	December 7	H. Wade Hibbard	R. V. Aycock	Osmer Edgar
Univ. of Nebraska. Lincoln, Neb.	December 7	C. R. Richards	M. E. Strieter	A. D. Stancliff
	1910			
Univ. of Maine, Orono, Me.	February 8	Arthur C. Jewett....	H. N. Danforth	A. H. Blaisdell
Univ. of Arkansas, Fayetteville, Ark.	April 12	B. N. Wilson	C. B. Boles	W. Q. Williams

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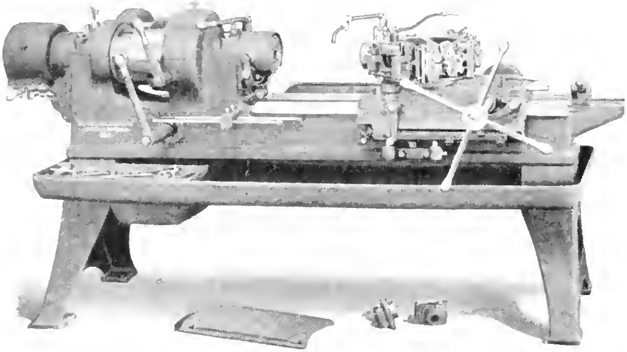

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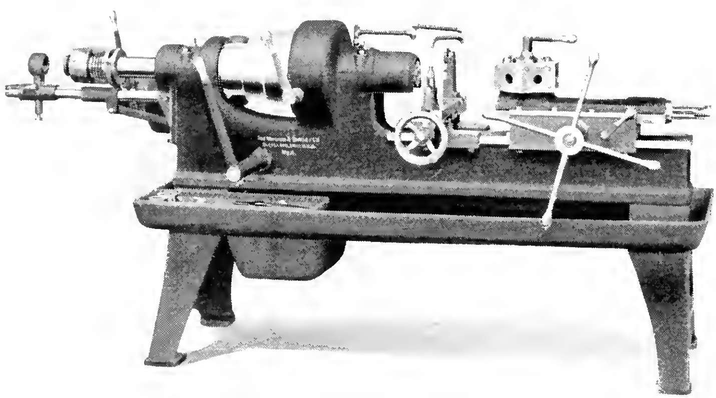

No. 6—2⅛ Bar Capacity—17″ swing

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We are now prepared to furnish Corliss engines of both simple and compound types, having Heavy Duty Tangye or Tubular Girder Beds, equipped with our new *"Franklin" patent horizontal gravity latch releasing gear,* enabling us to secure a rotative speed of 200 revolutions per minute.

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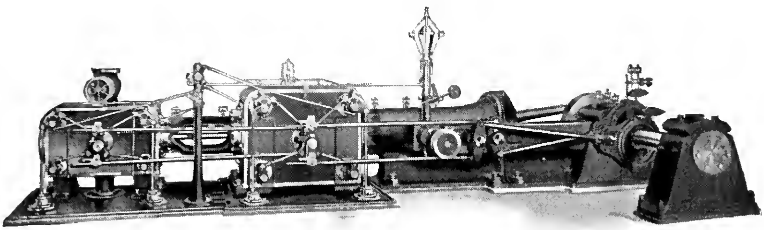
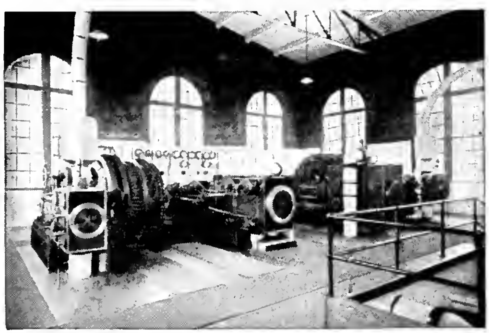


HEWES & PHILLIPS IRON WORKS NEWARK, N. J.



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Ball Engine Company

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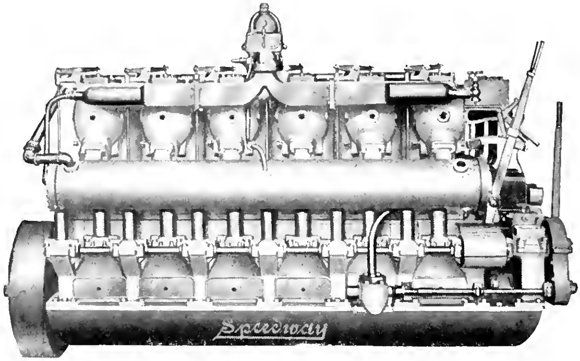

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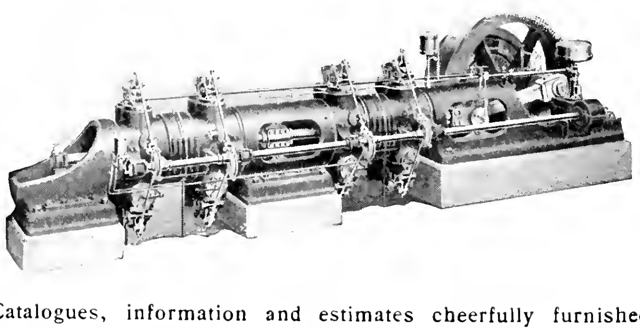

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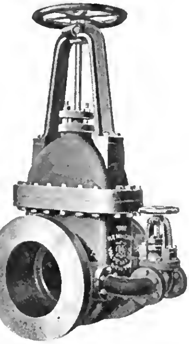

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"Graphite as a Lubricant" for 1910

This newest edition is just off the press with all the latest information on graphite lubrication. Big type, easy to read and worth reading. Write for free copy 199-C.

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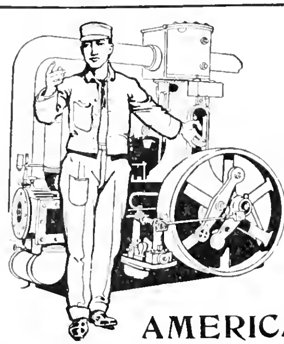

STEADY LIGHTS

Apartment houses, hotels and office buildings using incandescent electric lights supplied by current from a generator driven by an

American Ball Angle Compound Engine

have no trouble from unsteady lights. There is no interruption of service due to breaking of supply wires on account of storms or low candle power of lights due to excessive "line drop." American Ball Units keep the voltage constant and the lights burning to their full candle power. They are provided with sensitive automatic governors which take care of the widest variation in load. Where alternators are run in parallel there is no danger of the regulation being spoiled by cross currents as the Angle Compound Engine gives a practically uniform turning effort.

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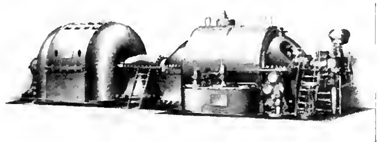

Westinghouse Turbines are built for using high pressure steam direct from the boilers, or for generating power from the exhaust of other engines

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Steam Turbines, Steam Engines, Gas Engines, Gas Producers, Condensers and Mechanical Stokers

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These motors are exceptionally satisfactory in the operation of machine tools, whether requiring constant speed or a frequent change in driving speeds. The qualities most responsible for their success are:

Efficiency and durability; reliability under the severest conditions; great overload capacity; low operating temperatures.

Type "S" motors are adapted to constant-speed service and to adjustable-speed service within moderate ratios, 1 to $1\frac{1}{2}$ or 1 to 2. Type "SA" motors have auxiliary commutating poles and are adapted for speed adjustments within the ratios of 1 to 3 or 1 to 4.

A considerable stock of both types in standard capacities is always available for immediate shipment.

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The American Society of Mechanical Engineers desires to obtain, through donations, purchase or exchange, the following periodicals:

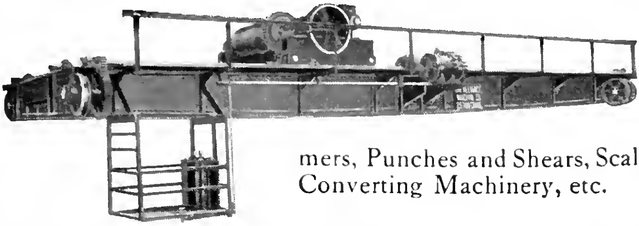
American Engineer, Chicago. Vol. 1. 1880.
American Gas Light Association. Vol. 1. Prior to 1875.
American Machinist. Vols. 1 and 2.
American Society of Naval Engineers. Vol. 1. 1889.
Mechanical Engineers, N. Y. Vols. 1-4. 1881-1882.
Scientific American. First Series. Vol. 1.
Die Gasmotorentechnick. Vols. 1-5, 6. Nos. 1-9.
Le Génie Civil. Vols. 1-23. 1880-1892.
Glaser's Annalen für Gewerbe u. Bauwesen. Vols. 1-7. 1865-1889.
Verein Deutscher Ingenieure. Vols. 1-7. 1857-63.
Der Schiffbau. Vols. 1-8.

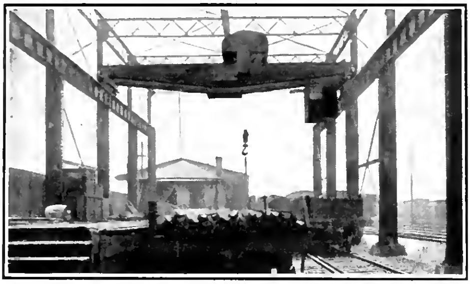
The American Society of Mechanical Engineers
29 West 39th Street, New York

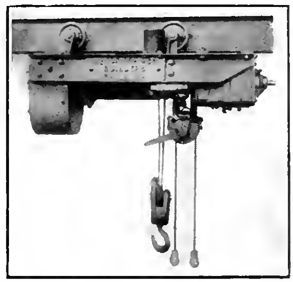
ADVERTISING SUPPLEMENT

SECTION 4

Hoisting and Conveying Machinery
Power Transmission







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Scientific American. First Series. Vol. 1.
Die Gasmotorentechnick. Vols. 1-5, 6. Nos. 1-9.
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Verein Deutscher Ingenieure. Vols. 1-7. 1857-63.
Der Schiffbau. Vols. 1-8.

The American Society of Mechanical Engineers

ADVERTISING SUPPLEMENT

SECTION 5

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ENGINEERING SCHOOLS AND COLLEGES

PROFESSIONAL CARDS

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SECTION 6

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from 1890 to 1908

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853	Pumping Engine Test with Superheated Steam, E. H. Foster	5	10
905	The Practical Application of Superheated Steam, Geo. A. Hutchinson	15	30
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THE

JOURNAL

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

CONTAINING
THE PROCEEDINGS

JULY 1910

MEETINGS IN BIRMINGHAM AND LONDON, ENGLAND, JULY 26 TO 29

JULY 1910 VOL. 32 No. 7

THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

PUBLISHED AT 2427 YORK ROAD . . . . BALTIMORE, MD.
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CONTENTS

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THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 32 JULY 1910 NUMBER 7

MEETING IN ENGLAND

Sir William H. White, Hon. Mem. Am. Soc. M. E., President of the Institution of Mechanical Engineers in 1889 when the Society last visited England officially, attended the Spring Meeting at Atlantic City and conveyed to the membership information concerning the perfected arrangements for the Joint Meeting of the Society with the Institution in England, July 26-28.

Upon arrival of the Celtic at Liverpool, Monday morning, July 25, the party will proceed to Birmingham by special train. On Tuesday morning, after an official reception by the Lord Mayor of Birmingham, papers on Handling Locomotives at Terminals will be presented by members of the Society. The afternoon will be devoted to a variety of professional visits and a garden party in the Botanical Garden will occupy the evening. On Wednesday morning there will be a topical discussion on High Speed Tools and Toothed Gearing, with further professional visits in the afternoon and a reception in the evening by the Lord Mayor of Birmingham, held in the Council House. Thursday will be devoted to visits to Coventry, Rugby, Litchfield, Kenilworth and Warwick where the castles will be visited,and Stratford-on-Avon, the entire party being conducted by special train to London in time for the conversazione in the headquarters of the Institution.

On Friday morning, members of the Society will present papers on the Electrification of Railways in the auditorium of the Institution of Civil Engineers. Several garden parties have been arranged for

the afternoon and the Institution dinner will take place in the evening in the Connaught Rooms, the largest dining hall in the city of London. Ladies are invited to this as well as to many of the other events. Visits are contemplated for Saturday to Windsor, the Japanese-British Exhibition and the Garden Club.

On Sunday special services will be held in Westminster Abbey, where seats will be reserved for the membership. It will be possible to make at this time an inspection of the Memorial Window recently erected to an Honorary Member of the Society, Sir Benjamin Baker, one of the three engineers who have been thus recognized. The window is exquisitely wrought and a material addition to the memorials in the Abbey.

The Committee of Arrangements appointed by the Council consists of Ambrose Swasey, Chairman, Charles Whiting Baker, Vice-Chairman, Dr. W. F. M. Goss, Geo. M. Brill, John R. Freeman, and, ex-officio, George Westinghouse, President, Wm. H. Wiley, Treasurer, F. R. Hutton, Honorary Secretary, Willis E. Hall, Chairman Meetings Committee, and Calvin W. Rice, Secretary. This Committee has appointed the following sub-committees: Transportation, Charles Whiting Baker, Calvin W. Rice; Entertainment, George M. Brill; Publishing and Printing, F. R. Hutton, F. R. Low; Finance, Wm. H. Wiley; Acquaintanceship, Dr. W. F. M. Goss. These sub-committees will provide for the material comfort of the party, and arrange for all official matters, including the publication of items of interest in regard to the Society in the daily newspaper on board ship. It is proposed to make the entertainment of the members on their journey across the Atlantic unlike any ever attempted in ocean travel and souvenirs will be presented to the winners of the games, etc., arranged by the committee in charge.

Copies of circulars giving full details in regard to the trip, including contemporaneous events in Europe, such as the Passion Play at Oberammergau and the International Exposition at Brussels, may be secured from the Secretary on application. Accomodations may yet be obtained from the White Star Line by any members who have failed to make an earlier reservation.

TECHNICAL VISITS

In addition to invitations conveyed to the membership some time ago, the following places of technical interest will be open to visits from the membership: In the Grand Ducal Technical High School

of Darmstadt, the machine construction laboratories, testing apparatus and electrotechnical institutions; Physikalischer Verein of Frankfort-on-Main; Hanover Machine Works of Hanover; de Fries & Cie, Düsseldorf, makers of horizontal boring and milling machines; and Hans Renold, Ltd., Manchester, England, makers of driving chains.

INTERNATIONAL EXHIBITION AT ST. PETERSBURG

Following the joint session in Birmingham of this Society with the Institution of Mechanical Engineers, at which a symposium is to be given on the electrification of railways, there is to be an international exhibition at St. Petersburg on the application of electricity to steam railways. This is to be held under the auspices of the Imperial Russian Technical Society, opening from the 15th to the 18th of August and closing three months later. The exhibits are to consist of rolling stock, apparatus for the equipment and handling of trains, drawings, photographs, descriptions of central stations, both steam and water power, drawings, models of track and roadway, data upon transmission lines, different systems of distribution, equipment of repair shops, general information upon cost of operation, railway exploitations under way in Europe and America, statistics, etc. There will be a special track, two miles long, for the trial of electric and motor cars.

ST. LOUIS MEETING, MAY 28

A meeting of the local members of The American Society of Mechanical Engineers with the Engineers Club of St. Louis was held Saturday evening, May 28, in the Club rooms, 3817 Olive St., St. Louis, Mo. Prof. Edw. C. Schmidt, associate professor of railway engineering at the University of Illinois, presented his paper on Freight Train Resistance; its Relation to Average Car Weight, also given at the Spring Meeting of the Society. Through the courtesy of the University of Illinois, the Illinois Central Railroad and the Terminal Railroad Association, the railway test car by which the data in the paper was obtained, was brought to St. Louis for the meeting and was open for inspection between 2 and 5 o'clock Saturday afternoon in the Eighteenth Street Yard of the Terminal Association. This car is equipped with all the apparatus necessary for carrying on train resistance experiments, as well as with auxilary apparatus which facilitates the making of locomotive road tests, and during the tests the apparatus within the car makes, autographically upon a chart 36 inches wide, a

record of drawbar pull, speed, time, air brake cylinder pressure, wind velocity and wind direction.

The meeting proved to be one of much interest and was well attended. The paper was discussed by Robert Moore, Past-President of the American Society of Civil Engineers, F. B. Fisher, Prof. H. Wade Hibbard, and others.

BOSTON MEETING, JUNE 1

A meeting of The American Society of Mechanical Engineers with the Boston section of the American Institute of Electrical Engineers and the Boston Society of Civil Engineers was held at Huntington Hall, Boston, on the evening of June 1. A dinner to Lewis B. Stillwell, President of the American Institute of Electrical Engineers, preceded the meeting, at which many prominent in engineering circles in New England were present. Prof. I. N. Hollis, Mem.Am.Soc.M.E., chairman of the committee on the proposed engineering building in Boston, spoke of the studies which had been drawn up of the building. These, he said, were based upon the arrangement of a permanent home for the several societies, clubhouse facilities, a joint library, auditorium, and mercantile headquarters. He was followed by several other speakers who spoke of the advantages which such a building would afford.

At the general meeting, President Stillwell made the address of the evening on the Conservation of our Natural Resources, special consideration being given to the subjects of water power and forestry. An extended discussion of the paper followed in which Prof. Geo. F. Swain, Mem.Am.Soc.M.E., C. T. Main, Mem.Am.Soc.M.E., Henry F. Bryant and Dr. A. E. Kennelly took part.

A REQUEST FOR 1903 POCKET LIST

A copy of the Pocket List for 1903 is needed to complete the files of the Society. Any member willing to furnish a copy will please communicate with Calvin W. Rice, Secretary, at the rooms of the Society.

THE SPRING MEETING

The Spring Meeting was held at Atlantic City, N. J., May 31–June 3, 1910, at the Marlborough-Blenheim, with an attendance of 135 members and 119 guests. The Meetings Committee had arranged a strong professional program and the Local Committee, comprised of Pennsylvania and New Jersey members residing in the vicinity of Atlantic City, under the Chairmanship of James M. Dodge, Past-President, gave a cordial welcome to the visitors and contributed to their pleasure in various ways in a generous and most acceptable manner

In place of the usual reception on the opening evening, there was an informal reunion of members and guests in the parlors of the Marlborough-Blenheim. Henry G. Morris, Chairman, Wm. R. Conard, Kern Dodge, Edward P. Harris, T. F. Salter, and J. A. C. L. deTrampe made up the committee in charge. Throughout the whole convention an air of informality and freedom pervaded, permitting the renewal of friendships and the forming of acquaintances without necessity for attending set functions and without the sense of being formally entertained.

Business and Professional Session, June 1

The meeting of Wednesday morning was called to order at ten o'clock by President Westinghouse and the report of the Tellers of Election to Membership presented as follows:

MEMBERS

Best, W. J.
Blakeslee, F. A.
Brown, Edward W.
Bryant, William L.
Burch, Henry Kenyon
Carson, W. R.
Chapman, Cloyd M.
Chapman, H. B.
Clark, Frank H.
Cone, H. I.
Cooley, E. S.
Coster, E. H.
Cressler, A. D.
Cummings, Byron
Davis, W. J., Jr.
Doane, John A.
Dorward, D., Jr.
Ernsberger, M. C.
Fenn, R. W.
Frost, Harwood
Fuller, George W.
Fuller, J. W., Jr.
Gallup, David L.
Ganz, Albert F.
Hallett, Edwin S.
Hammond, John Hays
Herschel, W. H.
Hodgson, Alec W.
Holmes, U. T.
Kingsley, F.

MEMBERS

Lebrecht, A.
Lester, C. R.
London, Wm. J. A.
Loring, Harrison, Jr.
Lundgren, Chas. G.
McLeod, Adolphus A.
Marot, W. G.
Merrell, Irving S.
Metcalf, Frank H.
Miller, John F. G.
Moody, Lewis F.
Neidhardt, J. Wm.
Oatley, Henry B.
Parr, Harry L.
Paulsmeier, A. C.
Peterson, C. H.
Porter, Hollis P.
Redfield, Snowden B.
Sanford, George R.
Sayer, Eugene Y.
Schlatter, R.
Scollan, John J.
Sessions, F. L.
Shallcross, W. C.
Shaw, Joseph D.
Sperry, Elmer A.
Stevens, Edson M.
Sumner, Eliot
Tenney, Theodore S.
Van Patten, W. E.
Westcott, V. S.
Whiteside, W. H.
Wiggin, R. M.
Winsor, Paul
Wyatt E. W.
Yeomans, Lucien I.
Zowski-Zwierzchowski, [S. T.]

PROMOTION TO MEMBERS

Batten, P. H.
Bishop, Frank
Bursley, Jos. A.
Dietz, Carl F.
Emerson, R. W.
Kennedy, F. L.
King, Roy Stevenson
Mahl, Frederick W.
Marshall, S. M.
Satterfield, H. E.
Young, C. D.
Young, John M.

ASSOCIATES

Burgess, Frank
Cobb, S. P.
Cooley, H. N.
Sears, Frank M.
Thompson, O. C.
Thorn, Charles N.
Whitcomb, Lawrence

PROMOTION TO ASSOCIATES

Hawley, Wm. P.
Henes, Louis G.

JUNIORS

Abrahams, M. L.
Adams, John
Bailey, Alex. D.
Bancroft, Geo. A.
Barnes, Arthur F.
Barron, C. M.
Bedell, E. H.
Bonner, Richard O.
Brady, J. B.
Brown, Walter E.
Burgess, A. Bradley
Carter, Harold Thomas
Casserly, T. D.
Clark, W. Van Alan
Cook, H. H.
Cook, William H.
Corlette, Glen H.
Correa, W. H.
Crute, W. R.
Cunningham, Geo. H.
Davock, H. N.
Dubarry, Ed. G.
Ellenbogen, S. A.
Emerson, R.
Ennis, H. V.
Fekete, Stephen I.
Fisher, J. O.
Foley, Walter J.
Gast, George Fred
Gernandt, W. G.
Gladfelter, H. S.
Grant, Chas. C.
Hall, Dwight K.
Hartley, H. D.
Heidelberg, Fred M.
Henderson, C. T.
Hey, Harry A.
Hood, Warren B.
Husted, C. M.
Keables, Austin D.
Lange, H. B.
Lines, W. H.
McCreery, J. Harold
McKibben, H. B.
Morris, Thos. B.
Mudge, S. T.
Nelson, B. S.
Painter, J. G.
Peper, John H., Jr.
Price, William T.
Roesler, Rudolph

JUNIORS

Ross, Philip L.	Sloane, Charles O'Conor	Thoma, Charles, Jr.
Rowlands, D. D.	Snow, N. L.	Terwilliger, Gerald E.
Rowley, R. L.	Sprau, W. C.	Thoma, Walter
Schoenijahn, R. P.	Stockwell, R. K.	Webster, L. B.
Sharp, J. T., Jr.	Swartwout, Everett W.	Wick, James L.
Sievers, E. J. J.	Taylor, H. B.	Wilson, R. A.
Woodman, Forrest E.		Zachert, A. R.

The following amendments to the Constitution were proposed by the Tellers on Amendment to the Constitution, and adopted by the meeting:

C 10 An Associate shall be thirty years of age or over. He must have been so connected with some branch of engineering or science, or the arts, or industries, that the Council will consider him qualified to coöperate with engineers in the advancement of professional knowledge.

C 11 A Junior shall be twenty-one years of age or over. He must have had such engineering experience as will enable him to fill a responsible subordinate position in engineering work, or he must be a graduate of an engineering school. A person who is over thirty years of age shall not be eligible to membership in the Society as a Junior.

C 45 The Standing Committees of the Society to be appointed by the President shall be: Finance Committee, Committee on Meetings, Publication Committee, Membership Committee, Library Committee, House Committee, Research Committee, Public Relations Committee.

Following this was a discussion on a proposed Bill for Licensing Engineers, introduced in the recent session of the New York Legislature. In explanation, Charles Whiting Baker, chairman of a committee appointed by the Council to investigate the subject, explained that the bill had called for the licensing of all grades of civil engineers, but that afterwards it was extended to all branches of engineering, requiring engineers to pass an examination and pay a license fee of \$25 for the privilege of practicing in their profession. The Board of Regents would have authority to appoint a special board of examiners before which every engineer desiring to practice would have to pass an examination. The engineering colleges of New York would be under the control of the same Board of Regents.

It was felt that the passage of such a bill would be injurious and a number of prominent engineers appeared at Albany in opposition and owing to their representations the bill was withdrawn by its promotor, with the understanding that it would be amended and offered at a later time.

The special committee appointed by the Council had met and adopted resolutions upon the subject of the pending bill, substantially as follows:

That it is the sense of this committee that legislation affecting the privileges and status of engineers can be most wisely originated by conference between legislators and representatives of the national engineering societies, and that the attention of legislators proposing legislation be invited to this procedure as natural and regular.

To request the Council of the Society to communicate with the Committee on Education to request the State Assembly that further action on this bill be postponed until after the Spring Meeting of The American Society of Mechanical Engineers, to be held in Atlantic City, May 31-June 3, at which meeting the subject will receive discussion.

To request the Secretary of the Society to confer with his colleagues, secretaries of the foreign technical societies, and seek to obtain such information as possible in regard to the necessity of the possession of certificates of competency, or other forms of license.

At a meeting of the Council just held at Atlantic City, a new Committee of Public Relations was authorized, one of the duties of which will be to act on any further legislation affecting the interests of members of the engineering profession. The movement for licensing engineers is bound to come up repeatedly in the legislatures of the various states and this Society should be prepared to take whatever action may be necessary to protect the interests of the profession as a whole from unwise and injurious legislation. This discussion ended the business meeting and the remaining time was devoted to the professional session.

There were four papers presented on the subject of Machine Construction and Operation. The first, The Shockless Jarring Machine, by Wilfred Lewis of Philadelphia, dealt with a new type of jarring machine in which the shock heretofore transmitted to the ground is absorbed as effective work by the machine itself, saving substantially all ramming time and opening the way to other economies. The paper was discussed by A. E. Outerbridge. E. H. Mumford and F. W. Taylor.

Prof. Walter Rautenstrauch of New York followed with his paper on A Comparison of Lathe Headstock Characteristics, concerned with the determination of the adaptability of a number of engine lathes to the economic performance of a standard task, that

of taking a predetermined area of cut on all diameters of work of mild and soft steel pieces, with high-heat steels, and showed the attempts of different manufacturers to meet the conditions favorable to these steels. Carl G. Barth, F. W. Taylor, Oberlin Smith and John Fritz discussed the paper.

The paper by Prof. A. L. Jenkins, of Cincinnati, on The Strength of Punch and Riveter Frames made of Cast Iron was next presented, giving a résumé of the important theories proposed for the analysis of stresses in straight cast-iron beams and presenting data on tests with small castings similar in shape to punch frames which showed a failure to verify any forumla. The discussors were James Christie, Walter Rautenstrauch, F. I. Ellis, Henry Hess, Oberlin Smith, Wilfred Lewis, J. S. Myers, S. A. Moss, George Westinghouse and John Fritz.

The fourth paper was upon Improved Methods in Finishing Staybolts and Straight and Taper Bolts for Locomotives, by C. K. Lassiter, of Richmond Va., and showed the advantage, in finishing staybolts, of automatically reducing in the center during the threading operations. Turning and facing under the head of straight and taper bolts were also treated. This paper was presented by Col. E. D. Meier, who added a few remarks.

Wednesday Afternoon and Evening

Wednesday afternoon was left free for recreation, roller chairs for the boardwalk being provided by the Local Committee throughout the afternoon. At three o'clock a special car conveyed members and guests to the grounds of the Golf Club at Pleasantville, where those who desired went over the course. Afternoon tea was served by the ladies.

In the evening there was a large attendance at the entertainment on the steel pier for which admission had been arranged. The Committee in charge consisted of Thos. C. McBride, Chairman, Thos. Eynon, James T. Halsey, John S. Muckle, John C. Parker and Wm. R. Webster.

Gas Power Section, Thursday Morning, June 2

J. R. Bibbins, Chairman of the Gas Power Section, called the meeting to order at ten o'clock and a few remarks were made by Secretary Rice congratulating the Section on its activities. Following

the business of the meeting, a paper on A Regenerator Cycle for Gas Engines using Sub-Adiabatic Expansion was presented by A. J. Frith of Chicago, which described a new cycle of 100 per cent theoretical efficiency, caused by the expansion line being steeper than that caused by free expansion, showing an avoidance of the loss of heat by water cooling, which in the older regenerative cycles overbalance the theoretical economy. The paper was discussed by S. A. Moss Wm. T. Magruder and Charles Whiting Baker.

The second paper was on Gas Engines for Driving Alternating-Current Generators, by H. G. Reist of Schenectady, N. Y., and brought out no discussion. The paper dealt with the solution of the problems of obtaining the best parallel operation of alternating-current generators when driven by means of gas engines, the most satisfactory solution being so to design the gas engine as to obtain nearly even rotation.

Two proposed Units of Power by Prof. Wm. T. Magruder, Columbus, O., was next presented and criticized the existing usage, proposing instead the terms boiler-power and gas-power, both of which were defined and described. Discussion was offered by Wm. Kent, H. G. Stott, J. C. Parker and E. D. Dreyfus.

The fourth paper presented was upon Operating Experiences with a Blast Furnace Gas Power Plant, by H. J. Freyn, of South Chicago, Ill., and contained a most complete account of elaborate tests made on the plant, extending over a period of two years. It was discussed by A. E. Maccoun, Jos. Morgan, W. E. Snyder, H. G. Stott, E. A. Uehling, Captain Tarr, Edw. Rathbun, Oberlin Smith and Charles Whiting Baker.

Professional Session, Thursday Afternoon

At the session of Thursday afternoon, commencing at two o'clock, four papers on miscellaneous subjects were presented, the first upon The Mechanical Engineer and the Textile Industry, by H. L. Gantt of New York. This was designed to point out a field and its possibilities in which the mechanical engineer had done little, that of industries which have not ordinarily come under his surveillance. There was no discussion.

A paper on the Elastic Limit of Manganese and other Bronzes by J. A. Capp of Schenectady, N. Y., followed, dealing with the elastic curves of brasses and bronzes, which are smooth curves, gradually bending as stress increases, and showing their lack of relationship to

the elastic limit indicated by the elastic curve. S. A. Moss, F. W. Dean, F. B. Gilbreth and E. A. Uehling discussed the paper.

The Hydrostatic Chord by Raymond D. Johnson, Niagara Falls, N. Y., was next presented. The name hydrostatic chord is given to a novel shape for large pressure conduits the function of which is to produce a tendency in the pipe to round out after the pressure reaches a certain mean value, causing an effort to increase the vertical diameter and tending to lift both the dead weight of the pipe shell itself and the top fill. The paper contended that these defects could be obviated with a shape properly designed on correct hydrostatic principles. There was no discussion.

The last paper was by Prof. Edw. C. Schmidt, Urbana, Ill., on The Resistance of Freight Trains and presented the results of tests made to determine this resistance and fully displayed and examined the test data. T. S. Bailey, W. T. Raymond, S. A. Moss, F. W. Dean, H. G. Stott, G. N. VanDerhoef, H. R. Cobleigh, Wm. H. Bryan, F. J. Cole, W. F. M. Goss and J. B. Blood discussed the paper.

Thursday Evening

On Thursday evening Honorary Membership in the Society was conferred on Rear-Admiral George W. Melville, U. S. N., Retired. At a gathering in the solarium of the hotel, Secretary Rice made formal announcement of the vote of the Council receiving Admiral Melville into such membership, and President Westinghouse voiced the pleasure of the Society in thus recognizing so distinguished an engineer. In replying, Admiral Melville expressed his appreciation of the honor bestowed upon him by his brother engineers. Sir William H. White, Past-President of the Institution of Mechanical Engineers and an Honorary Member of the Society, followed Admiral Melville and spoke of his splendid years of service to his country, of the sort sometimes disregarded by a man's own countrymen because of lack of perspective. He recalled the extraordinary naval experiences which the Admiral had undergone, in which he never at any time flinched from duty, and expressed himself in accord with Admiral Melville's feeling with regard to the honor conferred on him, since he also had been so signaled out by the Society. Walter M. McFarland of Pittsburg then read an address prepared by Admiral Melville for the occasion, on The Engineer's Duty as a Citizen.

A reception followed at which the membership were given an opportunity to meet Admiral Melville and Sir William White and dancing and refreshments concluded the evening.

Friday Morning, June 3

At the final session of the convention, held at ten o'clock Friday morning, four papers on Power Transmission were presented. The first, Ball-Bearing Lineshaft Hangers, by Henry Hess of Philadelphia, gave in detail the actual and relative first cost of a lineshaft installation, with plain bearings and ball bearings, and showed the saving secured by the latter. It was discussed by F. B. Gilbreth, H. J. Smith, F. W. Dean, J. S. Bancroft, C. J. Jackson, Harrington Emerson and G. N. Van Derhoef.

Following this, Prof. Wm. T. Magruder of Columbus, O., presented his paper on Experimental Analysis of a Friction Clutch Coupling, giving the results of five lines of investigation. It was discussed by H. J. Smith, who illustrated his discussion with lantern slides, G. N. Van Derhoef, E. P. Haines and Oberlin Smith.

A paper by Prof. C. M. Garland of Urbana, Ill., on An Improved Absorption Dynamometer, was next presented, describing a type of eddy-current dynamometer, adapted for the absorption of power given out by motors under test, with an enumeration of the conditions that should be fulfilled. Prof. C. M. Allen discussed the paper.

The fourth and last paper was by S. H. Weaver of Schenectady, N. Y., on Critical Speed Calculation, treating of the properties of equations of vibration, with curves showing the amplitude of vibrations at different speeds for various shaft loadings, spans and bearing supports. Henry Hess, S. A. Moss and M. Nusim discussed the paper.

Following the professional session, Jesse M. Smith, Past-President, presented the following resolution of thanks, which was unanimously adopted.

RESOLUTION OF THANKS

Whereas The American Society of Mechanical Engineers at the Semi-Annual Meeting held at Atlantic City in May-June 1910, desires to express its appreciation to those who have so bountifully provided for the entertainment of the visiting members,

Be It Resolved that the Secretary be instructed to extend the thanks of the Society and express the appreciation of its members and guests, to the local committees for their untiring efforts in providing for the comfort and pleasure of the visiting members.

Entertainment

During the entire convention roller chairs for the boardwalk were made available to the membership and admission furnished to the Golf Course at Pleasantville and to the entertainments on the piers.

The Ladies' Committee, with headquarters at the Marlborough-Blenheim, under the Chairmanship of Mrs. Charles Day, contributed in every possible way to the pleasure of the visiting ladies throughout the meetings, and tea was served at headquarters on Tuesday, Wednesday and Thursday afternoons, to which the members were also invited.

MEETING OF THE COUNCIL

The annual spring meeting of the Council was called to order at 5 p.m., Tuesday, May 31, 1910, in the director's room of the Marlborough-Blenheim, Atlantic City, N. J.

There were present, George Westinghouse, in the Chair, Charles Whiting Baker, J. Sellers Bancroft, R. C. Carpenter, H. L. Gantt, E. D. Meier, I. E. Moultrop, H. G. Reist, Jesse M. Smith, Ambrose Swasey, W. J. Sando, F. W. Taylor, W. R. Warner, W. H. Wiley and the Secretary.

The minutes of the meeting of April 12 were read and approved.

The following deaths were reported: James H. Blessing, W. W. Churchill, R. W. Emerson, H. S. Haskins, Walter C. Kerr, F. J. Plummer, I. I. Redwood, J. H. Bloomberg, M. W. Parsons, Jas. H. Bridge, E. P. Sparrow. The resignations of Asa S. Cook, W. W. Kuntz, A. S. Wardell, E. B. Arnold, Lewis Searing, Harry E. Paine, Chas. Wachalofsky, Jr., E. G. Rust and H. A. Dunn were accepted.

Voted: To adopt the report of the Executive Committee with regard to the conduct of meetings of the Society with the amendment "subject to the approval of the Council."

Voted: To refer the report of the Committee on Licensing Engineers, Chas. Whiting Baker, Chairman, to the Committee on Public Relations to be appointed.

The Secretary reported that the invitation of the Engineering Standards Committee of Great Britain for a conference on standards for screw threads had been declined, as there would not be sufficient opportunity in connection with the other meetings of the institution of Mechanical Engineers to hold such conferences.

Voted: To refer the report of the Special Committee on Balloting to a joint meeting of that committee with the Committee on Constitution and By-Laws.

Voted: To accept and adopt the report of the Special Committee on Identification of Power House Piping by Colors, H. G. Stott, Chairman, and to reappoint the same Committee, requesting them to make a report to the Council.

Voted: To adopt the amendment to B 37, as follows:

B 37 The Annual Meeting shall begin in the City of New York on the first Tuesday in December and continue from day to day as the Council may direct.

The Annual Business Meeting of the Society shall be held on the Wednesday following the first Tuesday of December.

The Semi-Annual Meeting shall be held in such a place and begin on such a day as the Council may direct, and continue from day to day.

The Semi-Annual Business Meeting of the Society shall be held immediately preceding the first professional session of the Semi-Annual Meeting.

Professional meetings of the Society for the reading and discussion of papers and for topical discussions may be held at such times and places as the Council may direct.

Announcements of all meetings of the Society shall be published in The Journal.

A notice of each Annual and Semi-Annual Meeting and each Annual and Semi-Annual Business Meeting of the Society shall be mailed by the Secretary to each member in each grade not less than 30 days before the date of that meeting and at least 30 days before each Special Business Meeting.

The Secretary reported that the Ballot on the amendment to the Constitution had been accepted by the Membership, thus adding the Public Relations Committee to the Standing Committees of the Society.

The Secretary reported the appointment of Carl Albert Johnson and Prof. T. G. D. Mack as Honorary Vice-Presidents to represent the Society at the opening of the Forest Products Laboratory at the University of Wisconsin.

On motion meeting adjourned.

STUDENT BRANCHES

COLUMBIA UNIVERSITY

On May 13, the following officers of the Student Branch at Columbia University were elected for the ensuing year: F. T. Lacy, president; W. H. Sellew, vice-president; J. L. Haynes, secretary; B. Rogowski, treasurer. A talk was given by Mr. Averill, managing editor of the Electric Railroad Journal, and lieutenant of the First Batallion, N.M. N. Y., on the engineering aspects of the batallion.

CORNELL UNIVERSITY

At a joint meeting of the Student Branch of The American Society of Mechanical Engineers and the Cornell Section of the American Institute of Electrical Engineers, on April 25, Wm. Macomber, of Buffalo, N. Y., gave an address on Patent Law. A social meeting followed, at which Prof. D. S. Kimball, Mem. Am. Soc. M. E., gave an illustrated talk on California.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

At a meeting of the Student Branch of the Massachusetts Institute of Technology, held May 13, C. H. Bigelow, Mem. Am. Soc. M. E., read an interesting paper on Inspection, which dealt particularly with reinforced-concrete and brick construction and their foundations. The paper was illustrated by lantern slides.

PENNSYLVANIA STATE COLLEGE

The last regular meeting for the year was held May 18, when the following officers were elected for the year 1910-1911: W. E. Heibel, president; J. A. Minnich, vice-president; G. M. Forker, secretary; J. A. Hassler, treasurer. Addresses were made by Charles E. Downton, on Modern Manufacturing Methods; by Prof. A. J. Wood, Mem. Am. Soc. M. E., on The Determination of the Specific Heat of Ammonia; by Prof. Hugo Diemer, Mem. Am. Soc. M. E., on The Human

Side of Engineering; and by I. H. Yoder (1910) and R. H. Mobley (1910), on the Interurban Railway proposition, from business and technical points of view.

PURDUE UNIVERSITY

At the meeting of the Student Branch of Purdue University, held May 4, 1910, Prof. M. J. Golden, Mem. Am. Soc. M. E., gave a talk on The Design and Construction of the New Shops of Purdue University.

STANFORD UNIVERSITY

On May 4 the following officers were elected by the Stanford University Student Branch for the year 1910-1911: J. B. Bubb, chairman; N. M. Day, vice-chairman; H. H. Blee, secretary-treasurer. A number of new members were elected. The business of the meeting was followed by a talk on Machine Shops, by E. P. Lesley, which was illustrated with lantern slides.

STEVENS INSTITUTE OF TECHNOLOGY

On May 10, 1910, Dr. John A. Brashear, Mem. Am. Soc. M. E., addressed the Stevens Engineering Society on The Contributions of Photography to our Knowledge of the Stellar Universe. The following officers were elected for the ensuing year: W. G. H. Brehmer, president; T. A. Horton, vice-president; J. G. Bainbridge, secretary; A. R. Lawrence, treasurer.

UNIVERSITY OF CINCINNATI

At the regular meeting of the University of Cincinnati Student Branch on May 20, the following officers were elected for the year 1910-1911: H. B. Cook, president; H. M. Stewart, vice-president; C. J. Malone, secretary-treasurer.

At the meeting on June 17 the members made an inspection trip to the plant of the Union Gas and Electric Company.

UNIVERSITY OF MAINE

At the meeting of the Maine Affiliated Student Branch on May 4, two papers were read, one by A. C. Hammond on The Mono-Rail Car, and the other by W. W. Hatch on Manual Training in the Secondary Schools.

UNIVERSITY OF MISSOURI

The Club of Mechanical Engineers of the University of Missouri was addressed on May 2, by J. R. Wharton on Refrigeration Insulation. On May 16, a paper was read before the meeting on Expert Testing of Locomotives, by Prof. H. Wade Hibbard, Mem. Am. Soc. M. E.

UNIVERSITY OF NEBRASKA

Prof. C. R. Richards, Mem. Am. Soc. M. E. delivered a lecture before the University of Nebraska Student Branch at its meeting of May 10, on Some Points in the Design of the Steam Turbine.

WISCONSIN UNIVERSITY

R. N. Trane (1910) gave a talk on An Electric Gas Meter before the meeting of the Student Branch of Wisconsin University, on May 5, in which he described the construction and operation of the Thomas gas meter. At the close, Prof. C. C. Thomas, Mem. Am. Soc. M. E., explained some of the finer details of the apparatus and the latest improvements on it, showing how the instrument is calibrated so that the reading of the watt-meter multiplied by a constant gave directly the quantity of gas passing through the meter.

NECROLOGY

WALTER CRAIG KERR

Walter Craig Kerr was a notable example of a type of engineering practitioner peculiar to the United States, the producer of great engineering achievements, who is a constructor as well as a consulting engineer. Such an engineer draws up and submits to his clients his own specifications for the work to be done for the latter; and then as supervisor or general contractor undertakes to carry these out under his own direction, his compensation coming to him not in the form of a consultant's fee, but of the profits from the financial undertaking. This system has been called the American system as distinguished from the British or European.

Mr. Kerr was born at St. Peter, Minn., on November 6, 1856. He was graduated from Cornell University in 1879 with the degree of B. M. E., and remained at Cornell for an interval of three years, as instructor and later assistant professor in mathematics. In 1882 he became a salesman and installing engineer for the Westinghouse Machine Company, designing the general installations for his company. In one year he was made manager of their eastern office. Through his realization of the common advantage to producer and consumer if the former can both supply the material and properly erect it, a company was formed in 1884 of which Herman Westinghouse, Mem.Am.Soc.M.E., William L. Church, Mem.Am.Soc.M.E., and W. C. Kerr were the nucleus. In this company and with the work it soon found for itself to do, Mr. Kerr was a forceful personality; and his faculty for organization and his energy as an officer have been large factors in the increase of its scope and the magnitude of its undertakings. He was vice-president at the start, and as the result of later changes in the personnel, he was president of the company at the time of his death. He was at one time vice-president of the Westinghouse Machine Company and was also a director of the Electric Properties Company at his death. New York City merchants recently elected him a vice-president of the Merchants' Association. He became a member of The American Society of Mechanical Engineers in 1886 and was active on its committees whenever asked to serve and full of helpful suggestions at many times. He was a member also of

the Engineers Club, the American Institute of Electrical Engineers, the Canadian Civil Engineers and other business and social organizations. He was an enthusiastic yachtsman at his home on Staten Island and effective governor of the local club. He died at Rochester, Minn., May 8, 1910.

It results of course from Mr. Kerr's advocacy of the constructive principle above referred to, that coöperation of engineer and contractor is to be preferred to an antagonism between them, that his monuments of achievement are those of his company rather than of any individual. This is both a loss and a gain, or perhaps is the algebraic sum of the two. By embodying their own designs in a materially existing structure, the name of the designs is not lost, as is so sure to be the case when they did not also construct. The grandeur of the structure as a material fact overshadows the mental achievement of the great concept, and the fact that it was the work of many obliterates the significance of the work of the organizing mind. But the work of the company has covered the construction of interurban electric lines in Michigan, Ohio, Missouri and New York states; power plant design and installation using both steam and water power for railways, lighting plants and producing factories. This firm electrified the Long Island Railway among others. Much of the power and hydro-electric plant for Cornell University was put in by their company, as Mr. Kerr had served as Trustee for the University for many years and was active in bringing Prof. R. H. Thurston to the Directorship of Sibley College in 1885.

But the most considerable single undertakings with which Mr. Kerr was identified will always be the engineering of the great Southern Terminal Station in Boston, Mass., and the new great uptown terminal of the Pennsylvania Railway at the end of its tunnels under the Hudson river, and the connecting subways. These have been splendid examples of the effective coöperation of the architects and engineers of the railways as owners and beneficiaries, and the consulting-constructing parties who were grouped together under Mr. Kerr's leadership. The Pennsylvania Terminal at 33d Street and 7th Avenue was visited by the Society in a body under the guidance of Mr. Kerr and Mr. Gibbs, by their invitation, at the time of the Annual Meeting in New York in 1909. Mr. Kerr was persuaded to present an account of the Boston Terminal at the Annual Meeting of the Society in December 1899[1] which is a model of a clear and concise presentation of a large topic.

[1]Transactions, vol. 21, p. 451, No. 845.

JAMES WELDON BRIDGE

James Weldon Bridge, an associate member of the Society, was born at Atlanta, Ga., March 24, 1873, and educated in the public schools of Atlanta, receiving in 1892 the degree of B.S. of M.E. at the Georgia School of Technology.

His early shop experience was with the Atlanta Consolidated Street Railway Company from 1894 to 1898, at which time he entered the drawing room of the Atlanta Railway and Power Company, becoming general foreman of shops in 1900. In 1902 he became superintendent of the manganese mines, Georgia Iron and Coal Company, and afterwards held various positions of importance with city and interurban railway companies. At the time of his death, December 20, 1909, he had just taken up the work of general manager of the Pittsburg, Monongahela & Washington Street Railway Company, stationed at Monongahela, Pa.

Mr. Bridge was a member of the Sigma Alpha Epsilon fraternity, and entered this Society in 1905.

FRANCIS JOHN PLUMMER

Francis John Plummer of Norwich, Conn., died April 5, 1910, and was buried at Worcester, Mass.

Mr. Plummer was born at Lancaster, Mass., February 29, 1840. He was apprenticed from 1857 to 1860 to Ball & Williams of Worcester, Mass., and continued with them as journeyman machinist until 1863, subsequently becoming foreman and superintendent for Ball & Williams and R. Ball & Company, where he remained until 1868. He then entered the employ of the S. A. Woods Machine Company, of Boston, leaving them for a brief connection as partner with the firm of E. C. Taintor & Company, of Philadelphia. Returning to the Boston firm, he took charge of the works and acted as superintendent from 1878 to 1885. His next connection was with Goodell & Waters of Philadelphia, also builders of wood-working machinery, where he held for five years the position of designer of planing-mill machinery. In 1890 he became associated with C. B. Rogers & Company of Norwich, Conn., of which he was superintendent and manager until 1907, when ill health compelled his resignation. His work was almost exclusively the design and manufacture of wood-working machinery, especially planing, molding and sawing machines for general building and car work. Many of his inven-

tions are now extensively manufactured by the American Wood-Working Machinery Company.

Mr. Plummer was a member of Sedgwick Post, G. A. R., having enlisted from Worcester with the Third Batallion Rifles in April 1861; and of several masonic orders. He entered this Society in 1891.

ERNEST PACKARD SPARROW

Ernest Packard Sparrow, who died in Dorchester, Mass., on April 18, 1910, was born at Portland, Me., September 17, 1857, and received his early education from the Westbrook Seminary. In 1880 he was graduated from the Worcester Polytechnic Institute with the degree of B.S.

Mr. Sparrow's first shop experience was with the Indurated Fibre Company, Gorham, Mass. He was subsequently associated with the Fitchburg Steam Engine, the Mather Electric Light, the Thompson-Houston Electric Light, the Jarvis Engineering, the E. P. Allis, the Boston Rubber Shoe, and the New Brunswick Rubber companies. For the past few years he had been associated with the B. F. Sturtevant Company of Hyde Park, Mass., where he was engaged on special engineering work.

Besides being a member of this Society, Mr. Sparrow was affiliated with several benevolent orders and organizations.

ILTYD ISAAC REDWOOD

Iltyd Isaac Redwood was born in London, December 16, 1863. He was educated at private schools, attending courses in elementary mechanics and drawing, afterwards supplementing them by evening study.

He began his career as a chemist in 1879 when for two years he acted as assistant to his father, Dr. Theophilus Redwood of the Pharmaceutical Association of Great Britain. In 1882 he became assistant chemist in the laboratory of Young's Paraffin Light and Mineral Oil Company, Ltd., in Scotland, and in 1887 entered the employ of the Queen's County works of the Standard Oil Company, where he became successively chemist, foreman of various departments, assistant superintendent in charge of construction work, and draftsman. Since 1897 he had been technical manager and expert adviser of the English works of Borax Consolidated, Ltd., manufacturers of borax and allied products.

Mr. Redwood was a member of the Society of Chemical Industry, the Royal Society of Arts, and the Aëronautical Society of Great Britain. He entered this Society as an associate in 1890 and was made a full member in 1903. He was the author of several works, namely, Ammonia Refrigeration; Mineral Oils and their By-Products; Lubricants, Oils and Greases; and was a recognized authority on chemical engineering.

WILLIAM NELSON PARSONS

William Nelson Parsons was born at Northampton, Mass., February 15, 1869, and received his technical training as a special student in mechanical engineering at Cornell University.

Mr. Parsons served his apprenticeship as a machinist with Charles C. Herrick of Northampton and later entered the employ of the Deane Steam Pump Company, Holyoke, Mass., and the Stanley Electric Manufacturing Company, Pittsfield, Mass. In 1900 he was employed in the drawing room of the Taft Pierce Company of Woonsocket, R. I., and at various times subsequently with the Goulds Company of Seneca Falls, N. Y., the Royal Electric Company of Montreal and the Steamobile Company of America. At the time of his death, April 24, 1910, he was chief draftsman for the Buffalo Bolt Company of North Tonawanda, N. Y.

JONAS HENRY BLOOMBERG

Jonas Henry Bloomberg was born in New York City, February 2, 1870. He was educated in the public schools and later at the College of the City of New York, leaving there in 1900 to go to Mexico where he devoted himself with great success to sugar house machinery. He built and designed most of the modern sugar houses and distilleries there, the more important ones being at the Rio Vista Plantation, the Almonte Plantation and the La Crosse Plantation. At the time of his death, April 27, 1910, he was consulting engineer of the Rio Tamasopo Sugar Company of Tamasopo, S. L. P.

Mr. Bloomberg was a member of the National Geographical Society of Washington, D. C., as well as a member of this Society.

THE ENGINEER'S DUTY AS A CITIZEN

By Rear-Admiral Geo. W. Melville, U. S. N., Ret.

Honorary Member of the Society

Doubtless everyone present has read Macaulay's famous chapter, in his History of England, which describes the conditions obtaining in 1685. This chapter is one of the most wonderful descriptions in all literature, giving as it does the details of every feature of the life of that time, some 200 years ago. I refer to this account because I want you to contrast it with the conditions of today, to which we are so accustomed that it requires some effort to remember that the comfort and conveniences of the poor man of today are beyond the wildest dreams of the wealthiest men of the period described by Macaulay. At that time there were no sidewalks and the streets were unlighted; the highways became bogs in rainy weather, and highway robbery was almost a recognized profession; sanitation and sewerage were unknown, and refuse heaps accumulated under the windows of the great and the wealthy; it was dangerous to go out alone at night; and it was still legal to hang the unfortunate who stole a loaf of bread.

2 Macaulay remarks in one place that at such fashionable watering places as Bath, the nobility had to put up with accomodations at which their servants in the year 1850, in which he was writing, would turn up their noses.

3 Now when we compare the two periods and remember that there is hardly a branch of human activity in which there has not been the greatest improvement, we are naturally led to ask to whom is the improvement due.

4 In all fairness, we should doubtless have to say that most of the professions have had a part in the amelioration of conditions, although the student of history remembers with regret how the great lawyers opposed the remission of the death penalty for what we would now consider minor offenses.

5 Physicians are undoubtedly entitled to much credit for advances in medicine, surgery, sanitation and hygiene, and we might

Address given at the Atlantic City Meeting of The American Society of Mechanical Engineers, 29 West 39th Street, New York, July, 1910. All papers are subject to revision.

go on and give credit to others. It seems to me, however, that when some future Macaulay describes the condition of the United States at the beginning of the twentieth century and attempts to award the credit for the existing comforts and conveniences, the major part must be given to the profession of engineering. Within 100 years after the time described by Macaulay, Watt had so far perfected the steam engine as to bring about the beginnings of the factory system, making possible the low cost of clothing and of articles of manufacture of every kind. In a century the steamboat and the railroad had come into being. Then we have gas for illumination and the telegraph for rapid communication, and so on down the line to the present day with its electric light, electric railroad and telephone, every one due to the engineer.

6 Added to the superior facilities of communication by railroad and steamer came mechanical refrigeration, which enables the densely populated countries of the old world to be supplied with meats from the great plains of the new, and these superior means of transportation have provided the rapid movement of food products so that the whole world contributes to the delicacies of our table, no matter where we are.

7 The contrast between the conditions of the great cities of the period described by Macaulay wi h those of today is startling. Cities were without the conveniences which a country town of moderate size would now consider absolute necessities. The systems of water distribution, sewerage, street paving, etc., are all the work of the engineer, and filtration plants obviously are engineering works, even if we consider their inception to be due to the medical men.

8 Perhaps you ask why I should go into these details which are common knowledge, when their mention can give little additional information. My reason is that I want to emphasize the facts as a basis for the discussion of the question: What does the engineer owe to society when society owes so much to the engineer.

9 In the early history of the race, when war was the almost constant condition it was inevitable that the great warrior should become the leader and ruler of the people. As time went on, the engineer developed, as we know from the wonderful works of antiquity like the great aqueducts, the bridges, tunnels and roads; but, from the past, had come the tradition lodging leadership in the warrior caste, where it remained for many centuries, and, indeed, has still a tendency to remain in monarchical countries.

10 During the last century, wars have been less frequent, and,

due to the engineer, commerce has become so prominent that while the hereditary nobility still linger on the scene, their titles have become almost meaningless. This was particularly noticeable when one of the English dukes served in the quartermaster's department during the Boer war in a subordinate capacity, and still more so in the war between Russia and Japan, when only one Russian general was a member of the nobility.

11 I think you will see the point to which I am leading; namely, that in this "age of the engineer," he should not rest content simply with doing the work which makes for our comfort and happiness, at the command of others, men who are lawyers or simply business men, but that the engineer himself should take a vital and directing part in the administration of affairs. I know the objection that an engineer's professional work is so engrossing and exacting that he cannot become a politician in the sense that a politician is a man who gives all his time to pulling wires and filling offices. This is doubtless true, but where it is a matter of self-interest, the engineer, like other men, can find time for this extra work.

12 We Americans are fond of claiming that we have the greatest country and the most free and best government in the world. That government, however, for its efficiency and integrity depends upon us as citizens, and it ought to be a matter of the greatest pride to every American to do his part, so far as lies in him, to make the country and its government better and happier every year.

13 In view of the enormously important part which the engineer plays in the life of today, it is incumbent upon him, more than upon most other men, to take a vital interest in the work of government and to lend his trained ability and judgment to its perfection. I do not mean of course that the engineer should do routine professional work for the government without compensation, but that in the discussion of public improvements and the administration of governmental departments, he should take an active public stand to influence and guide the non-expert part of the population.

14 It is notorious that enormous amounts of money have been squandered on great public works because they were undertaken in a way which every engineer knew must be inefficient and uneconomical. If all of us as engineers had a keen sense of our duty in this respect, and would properly utilize our experience and ability through the daily press, the magazines and the reviews by public discussion and in the daily intercourse of life, as well as by impressing the truth upon our representatives in municipal and national affairs, I believe we would accomplish an immense amount of good.

15 It will be understood, I am sure, that in this I refer almost entirely to the relations of engineers to society in general, and not to other professional men. For many years engineers have been most generous in making public to their technical brethren the results of their experience, and our own Proceedings are full of instances. It would be impossible to name more than a few, but perhaps the most notable case was that of Past-President Taylor in the publication of the results of his life work of research on the Art of Cutting Metals.

16 A problem of foremost importance at the present time is the management of labor to secure efficient work and satisfied men. It is probable that the direction of more than 90 per cent of the skilled labor is in the hands of engineers. Most emphatically is this a case where engineers owe a great duty to society. It is, therefore, an especial pleasure to recognize that some of our own members have played a foremost part in the best work that has been done in devising plans for compensating labor which will stimulate the men to their best efforts and reward them adequately. The names of Halsey, Taylor, Gantt and Emerson will at once occur to you

17 It would be inappropriate in this brief address to attempt a detailed discussion of the labor problem, but I feel that I shall voice the sentiment of every one present when I say that the effort of every patriotic American should be exerted to maintain absolute freedom of contract in labor matters as in all others. Just as we are opposed to monopoly by capital, so we are to the same thing by labor.

18 No reasonable man objects to labor organizations, as such. They have undoubtedly been the cause of much benefit to the men. The danger with them, as with political organizations, is the formation of a machine which utilizes the organization solely for the selfish interests of the members of the machine. There can be no doubt whatever that many strikes are against the real wishes of a majority of the men, who are overborne by the machine and its adherents; and it is also true that the net result of nearly all strikes is an actual loss to the men. The problem is an exceedingly difficult one and requires the greatest wisdom, patience and tact for its complete solution; if, indeed, taking human nature as it is, we can ever hope for its removal from the list of worries of the manager of great enterprises.

19 Many questions prominently before the public are peculiarly such as require engineering knowledge for their proper understanding and regulation. The word trust has come to have such a sinister meaning that it is only necessary to fasten it upon an enterprise to render it criminal in the popular estimation. We have recently heard a great deal about the so-called Water Power Trust, the charge being

that all the available power sites were being grabbed so as to subject our citizens at some future time to the payment of tribute for electric power derived from them. I am not concerned, at the moment, with a discussion of monopolies, which we all deprecate, but to point out that engineers know these water powers cannot be made available except by the expenditure of large sums of money. Indeed, it would be easy to point out the fortunes that have been lost in the attempted exploitation of these supposedly lucrative natural gifts. The general public is utterly misled by statements that these power sites are obtained for nothing, the idea being that the development is a matter of small expense. Here the engineer can do a work of real benefit by disseminating correct information.

20 Again, in the consideration of public service corporations, the engineer knows the cost of installation and operation, and so can discuss intelligently whether rates are fair or exorbitant, and whether capital represents real investment or water. These are problems of the greatest importance, and for their proper solution, the electorate needs training that can be given by no one else so well as by the engineer.

21 About a year ago, at our Washington meeting, I did what I could along this line by pointing out mistakes in connection with navy yard organization, and this illustrates very clearly what I am advocating for all engineers. Here was a great department of the Government for which the annual appropriation now exceeds one hundred millions of dollars. Its administration had fallen into the hands of a man who started to make changes in the entire administration which would have been ruinous to efficiency; and yet, hardly a voice was raised in opposition. I even heard of a case where one of our leading engineering journals refused to publish a criticism of this system submitted to them through a man whom they knew and esteemed most highly, but who stated that the author was so situated that he could not permit his name to be used. Not only would the magazine not print the article but they did not take enough interest in this most important subject to study it for themselves and comment upon it.

22 I do not mean to imply that engineers never show public spirit in such ways as I have suggested: there are too many instances to the contrary. Our own Society and others which have taken part in the movement for conservation of our natural resources have set a good example, and other cases could be cited where individual engineers have shown commendable enthusiasm. These, however, are mostly cases of unusual importance and relatively infrequent. What I am

pleading for is a habit of mind that will cause engineers to take an active part in all public questions, great or small, where their knowledge and experience will enable them to contribute to the common good.

23 The movement which has been set on foot by Congress to establish a Bureau of Mines suggests an opportunity for the engineer to take an active part in public affairs. I question whether this idea might not be developed a little further by providing for a department with a Cabinet officer at the head, to be called the Department of Mines and Manufactures, with the scope implied by the title.[1]

24 When we think of the enormous values represented by the industries which would come within the purview of such a department, it seems only reasonable that they should be under the care of a Cabinet officer. If we are told that there is already the Bureau of Corporations, I would point out that the object of this proposed new department is quite different from that of the existing bureau which thus far, in the estimation of many, has done little or nothing to advance the interests of manufacturing, but has, in their opinion disclosed a spirit which is almost inimical. The department that I have in mind would aim to stimulate improvement and progress in manufactures and industries generally, in somewhat the same way that the Department of Agriculture has done for the farmers.

25 We have often heard engineers complain that the profession did not receive due praise and credit for its splendid work. This is true enough, but is the reason not very largely because the engineer hitherto has been content to do the work and then fade into the background, leaving the talking and the management to the lawyer and the politician? With the advance of technical education, engineers are more and more becoming the high officials of our large corporations. It is to these men, whose talents and trained ability have made them the leaders in manufacturing and in business, that the country has the right to look for leaders in the affairs of government, and not until the engineer of all grades has done his part towards the promotion of the highest efficiency of the Government can he truly say that he is, in the fullest sense of the term, a good citizen of the Republic.

[1]This address was prepared more than a month ago, and since that time the bill in Congress referred to above has become a law. The newspapers have published an item that consideration was being given to the formation of a Department of Public Works. This is along the same general line as my suggestion above for a Cabinet officer to head a Department of Mines and Manufactures.

THE ELECTRIFICATION OF RAILWAYS

AN IMPERATIVE NEED FOR THE SELECTION OF A SYSTEM FOR UNIVERSAL USE

By George Westinghouse, Pittsburg, Pa.
President of the Society

As an illustration of the wonders of the laws of nature, few inventions or discoveries with which we are familiar can excel the static transformer of the electrical energy of alternating currents of high voltage into the equivalent energy at a lower voltage.

To have discovered how to make an inert mass of metal capable of transforming alternating currents of 100,000 *volts into currents of any required lower voltage with a loss of only a trifle of the energy so transformed, would have been to achieve enduring fame. The facts divide this honor among a few, the beneficiaries will be tens of millions.*

1 In less than twenty-five years a new industrial and economic situation has been created by the development of apparatus to generate, distribute and utilize electricity. Not less than two thousand million dollars have been invested in plants to manufacture apparatus, in power houses to generate electricity, in lines of copper wire to transmit this mysterious energy, in construction of railways and their equipment, and in the manufacture of products unknown before the advent of electricity.

2 Large sums have already been spent in the electrification of portions of standard steam railways in England, continental Europe and America, and there is now available a fund of information of inestimable value to guide those charged with the selection of an electrical system for railway operations.

3 The president of our brother Institution of Mechanical Engineers, Mr. Aspinall, in his presidential address delivered April 23, 1909, placed the railway world under deep obligation for most valuable information upon the electrical equipment and operation of trains of the Lancashire & Yorkshire Railway, of which he is the

The American Society of Mechanical Engineers, 29 West 39th Street, New York, July 1910. All papers are subject to revision.

worthy and skillful general manager. His observations on the effects of low center of gravity and heavy inflexible motor trucks upon the permanent way are especially valuable in that they direct attention to costs which at first were not considered with sufficient care.

4 Believing unreservedly that the increased capacity of a railway and its stations, the economies of operation, and other advantages will bring about gradually the systematic electrification of steam railways, my wish is that the progress of the art may not be hampered and such electrification of our main lines delayed or rendered unprofitable by mistakes which experience, judgment and foresight may enable us to avoid.

5 It is my intention in this paper to direct attention to the necessity for the very early selection of a comprehensive electrical system embracing fundamental standards of construction which must be accepted by all railway companies in order to insure a continuance of that interchange of traffic which, through force of circumstances has become practically universal, to the great advantage of transportation companies and of the public.

6 Having been identified with railway operations for over forty years, and with the development of the electrical industry for twenty-five years, I feel that the time is ripe for such a selection unless we are willing to regard with complacency the extension of the existing diversified systems and the creation of conditions which will prevent the general use of the most practical methods of operation.

7 Indeed, the tendency seems to be toward diversity rather than unity, since different types of third-rail construction have been adopted, even for the several continuous-current systems in and about New York City, which renders interchange of cars or locomotives difficult or impossible.

8 Although the facts clearly show the contrary, there exists a popular impression that the electrification of railways is a simple matter, and that it requires only decisions by boards of directors to insure the immediate substitution of the electric for the steam locomotive.

9 The great difficulty in the electrification of standard railways is no longer the engineering problem of developing a locomotive and an electrical system which will operate trains, but it is a broad question of financial and general policy of far-reaching scope, considering the future electrification of railways in general as distinguished from isolated cases of limited extent, and requiring a combination of the highest engineering and commercial skill.

GAGE OF TRACK AND INTERCHANGE OF TRAFFIC.

10 In the first days of railway operation, there was probably no idea of an interchange of traffic involving the use of the engines and cars of one railway upon the lines of another railway. It then made no difference whether the gage of track were 4 ft. $8\frac{1}{2}$ in., the one ultimately selected, or one of a greater or lesser width by a few inches. The gage selected by Stephenson was a practical one, fortunately, since it has become almost universal, with a strong probability that it will one day be absolutely so.

11 Stephenson's successful demonstrations prompted experimenters in other countries, who naturally failed to appreciate the inconvenience and losses which were to follow the adoption of different gages. The general tendency to extend along the line of least resistance, made it inevitable that a railway once started upon a certain gage would make no change, and thus there were developed systems of railways with different gages of track. In the early days too, there were those who believed it to their advantage to establish a gage of track that would absolutely prevent the cars and engines of a connecting line from coming upon their line.

12 In some cases in the United States the difference in gage was, fortunately as it afterwards proved, only $1\frac{1}{2}$ in., a difference successfully met, for the purpose of interchange of traffic, by the adoption of broad-tread wheels and minor changes in the track construction. In other cases, the gages adopted were 5 ft., 5 ft. 6 in., and 6 ft., and in some of these cases the necessity for through passenger traffic led to the changing of car trucks, at certain important places, so that passengers could be transported through to their destination without changing cars.

13 In 1878 there were in the United States eleven different gages of railroad tracks in addition to the standard gage of 4 ft. $8\frac{1}{2}$ in.

14 The absolute necessity for uniformity of gage of tracks both in the United States and Canada became so apparent that in due course all of the roads which had gages wider than 4 ft. $8\frac{1}{2}$ in. changed to the present standard. Among the remarkable achievements of engineering was the change of the tracks of an entire system of railway of some hundreds of miles within twenty-four hours, this change having, however, required months of preparation. The losses entailed in the change of gage and of equipment have ever since been serious burdens to most of those railways, in that the costs were in most cases covered by capital charges.

15 It may be conceded that, so far as steam railway operation

is concerned, there are now no obstacles to the interchange of traffic in the broadest sense, except in the size of vehicles in certain countries where the cost of changing tunnels and bridges would be prohibitive.

REQUIREMENTS FOR INTERCHANGE OF TRAFFIC

16 With these preliminary remarks I feel certain you will agree that to insure interchange of traffic, the fundamental requirements, so far as operation by steam is concerned, with full regard for safety, speed and comfort, are very few in number and are covered by the following:

a A standard gage of track.

b A standard or interchangeable type of coupling for vehicles.

c A uniform interchangeable type of brake apparatus.

d Interchangeable heating apparatus.

e A uniform system of train signals.

The additional fundamental requirements for electrically operated railways are:

f A supply of electricity of uniform quality as to voltage and periodicity.

g Conductors to convey this electricity so uniformly located with reference to the rails that, without change of any kind, an electrically fitted locomotive or car of any company can collect its supply of current when upon the lines of other companies.

h Uniform apparatus for control of electric supply whereby two or more electrically fitted locomotives or cars from different lines can be operated together from one locomotive or car.

17 Outside of economy in capital expenditure, and economy and convenience in operation by steam or electricity, it matters not whether each locomotive and car and the apparatus upon them differ from every other locomotive and car in size or details of construction, so long as the constructions are operative and the materials employed are used within safe limits.

DEVELOPMENT OF ALTERNATING-CURRENT APPARATUS

18 Having acquired a considerable experience in the introduction upon railways of the compressed air brakes and in the development of automatic electro-pneumatic signals, I was led in 1885, because of its general analogy to operations with which I was familiar, to interest myself in the American patents of Gaulard and Gibbs (a Frenchman and an Englishman), covering a system of electrical distribution by means of alternating currents, with static trans-

formers to reduce these currents from the high voltage necessary for economical transmission of electrical energy to the lower voltages required for the operation of incandescent lamps and other purposes.

19 No inventions ever met with greater opposition in their commercial development than those relating to the generation, distribution and utilization of alternating currents, and it is a matter of record that the opponents of those interested in developing the alternating system even sought, through public meetings and the appointment of commissions, and by various extraordinary means, to influence and prejudice public opinion.

20 Realizing the limitations of the continuous or direct-current system, I became thoroughly convinced that the extended distribution of electricity for industrial purposes could be secured only by the generation of alternating currents of high voltage and their conversion by static transformers into currents of various voltages. Notwithstanding, therefore, the frank disbelief in its practical value by eminent scientific authorities, among them the late Lord Kelvin, I entered actively into the development of the alternating-current system of generation and distribution of electricity which is now almost universally accepted as the ideal.

21 By 1888 Nikola Tesla had demonstrated the practicability of his induction motors, Oliver B. Shallenberger had perfected his meter for measuring alternating currents, and it had been proved that a direct-current motor with laminated armature and fields could be operated either by alternating or by direct currents. I then became thoroughly imbued with the belief that further invention and discovery would in time make alternating-current apparatus practically universal for almost every purpose.

22 In 1892 two single-phase motors of about 10 h.p. were built by the Westinghouse company to determine the possibilities of using alternating current for traction work. These motors were designed for 2000 alternations per minute and about 200 volts. They were of the series type, with commutators, and had a relatively large number of poles. These were placed upon a car and tested on a short piece of track with very short curves and rather steep grades. There was a transformer on the car on which there were several taps and the voltage was varied by means of single-pole switches. It was considered at that time that the system would be ideal for locomotive work, but as there were no such projects in view, no large motors of this type were built. This development is referred to more at length in Appendix No. 5.

23 All so-called continuous- or direct-current generators really generate alternating currents and transform them by a commutator into continuous current, and such a machine will, by the application of collector rings upon its armature, deliver both alternating and continuous currents. The use of the commutator, however, so limits the voltage that large quantities of power cannot be generated for economical transmission by direct current. A machine so constructed can also receive alternating currents through the collector rings and transform them into direct current. As thus used the apparatus is called a rotary converter. When the supply of alternating current is at very high voltage, there has to be interposed between this supply and the rotary converter a static transformer to reduce the high primary voltage to the permissible lower voltage.

ELECTRICAL SYSTEMS FOR RAILWAYS

24 As soon as these qualities of the alternating current had been demonstrated, active minds were directed toward the development of apparatus to meet conditions constantly presenting themselves, among the most important problems being the electrification of railways. In the twenty years that have elapsed, three important electrical systems for the operation of railways have been put into practical operation, all using alternating current in whole, or in part. These systems are:

- *a* The continuous- or direct-current system, usually spoken of as the "third-rail" system, which employs alternating current for transmitting power when the distance is considerable.
- *b* The three-phase alternating-current system with two overhead trolley wires.
- *c* The single-phase, alternating-current, high-tension system with a single overhead trolley wire.

25 In a notable case of the latter system, namely, that of the New York, New Haven & Hartford Railroad, the motors and controlling apparatus are arranged to utilize single-phase current from an overhead trolley wire at 11,000 volts, and also to be operated by current from the 650-volt third-rail system of the New York Central & Hudson River Railroad, thus making a demonstration of the wonderful flexibility of alternating-current apparatus.

26 The problem before the officials of the New Haven road was not merely the electrification of a division of a few miles of its track, rendered compulsory by legal requirements, but the selection of a system which would meet the needs of a great railway covering several

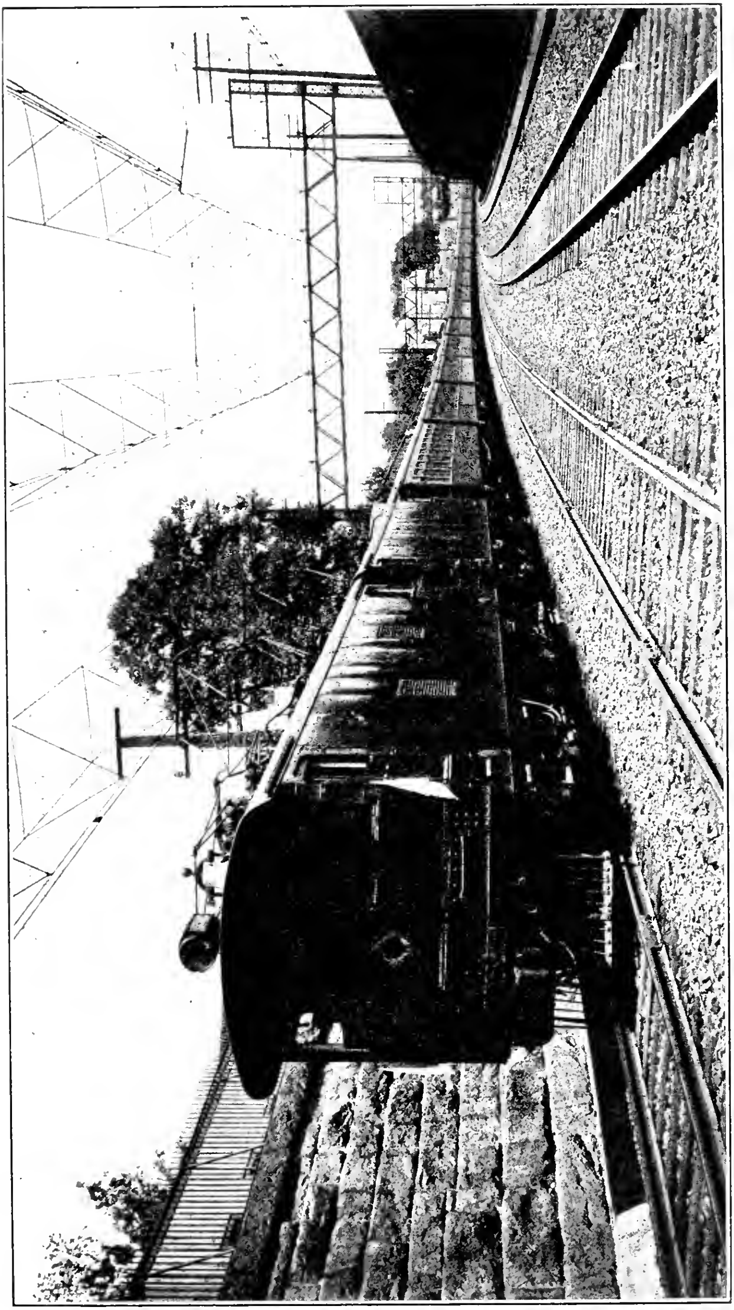


Fig. 1 Single-Phase Electrification of the New York, New Haven & Hartford Railroad

VIEW SHOWS TROLLEY WIRE SUPPORTED BY DOUBLE STEEL CATENARY CABLES SUSPENDED FROM LATTICE STEEL BRIDGES OVER THE FOUR TRACKS. THE ONLY ELECTRICAL CONSTRUCTION ON THE TRACK LEVEL IS THE SMALL COPPER BONDS CONNECTING THE RAILS.

states and having other congested centers of traffic which it might soon be desirable to electrify. In view of the fact that there had been no considerable demonstration of the single-phase system by actual use, and that the New Haven trains would be obliged to operate upon twelve miles of lines already equipped with the direct-current third-rail system, it must be conceded that the directors and management of the New York, New Haven & Hartford Railroad showed great courage and confidence in the judgment of their experts. and rendered to all other railroads a service of the highest character, when they selected the single-phase system for the electrification of the line mentioned.

27 As the single-phase method of operation is comparatively recent and is not so well known as the other systems, extended particulars are given in the appendices upon the extent of operation by this system, and upon the results attained in its use by the New York, New Haven & Hartford Railroad. The important experiences gained on that railroad furnish very important data to aid in the selection of a uniform system of electrical railway operation.

28 The paper[1] by Mr. George Gibbs, chief engineer of electric traction of the Pennsylvania Railroad, with reference to the electrifications by that company, submitted in June of this year to the International Railway Congress at Berne, Switzerland, gives most valuable particulars in regard to the practical electrical operation of a standard railway.

29 When the officials of the New York Central Railroad and those of the New York, New Haven & Hartford Railroad, who now have had an unusual experience, also present their available facts as to cost of installation, of maintenance and of operation, the railway world will have very complete information.

30 The results of the working of the three-phase system in Italy and Switzerland have been very prominently before the world for several years, and its successful use there has been a material factor in the development of confidence in electricity for the operation of railway trains. At the present time, the Italian Government is installing upon the Giovi line, which is a heavy-grade branch leading out of Genoa, a service for which twenty locomotives, rated at 2000 h.p., are now being constructed in Italy. The operation of this

[1] The report is entitled Electric Traction: Electric Traction on Large Railroads; Continuous Current; Alternating Current (Monophase or Polyphase); Comparative Net Cost. It appears in the Bulletin of the International Railway Congress Association, under Question 8, Report No. 2, by George Gibbs.

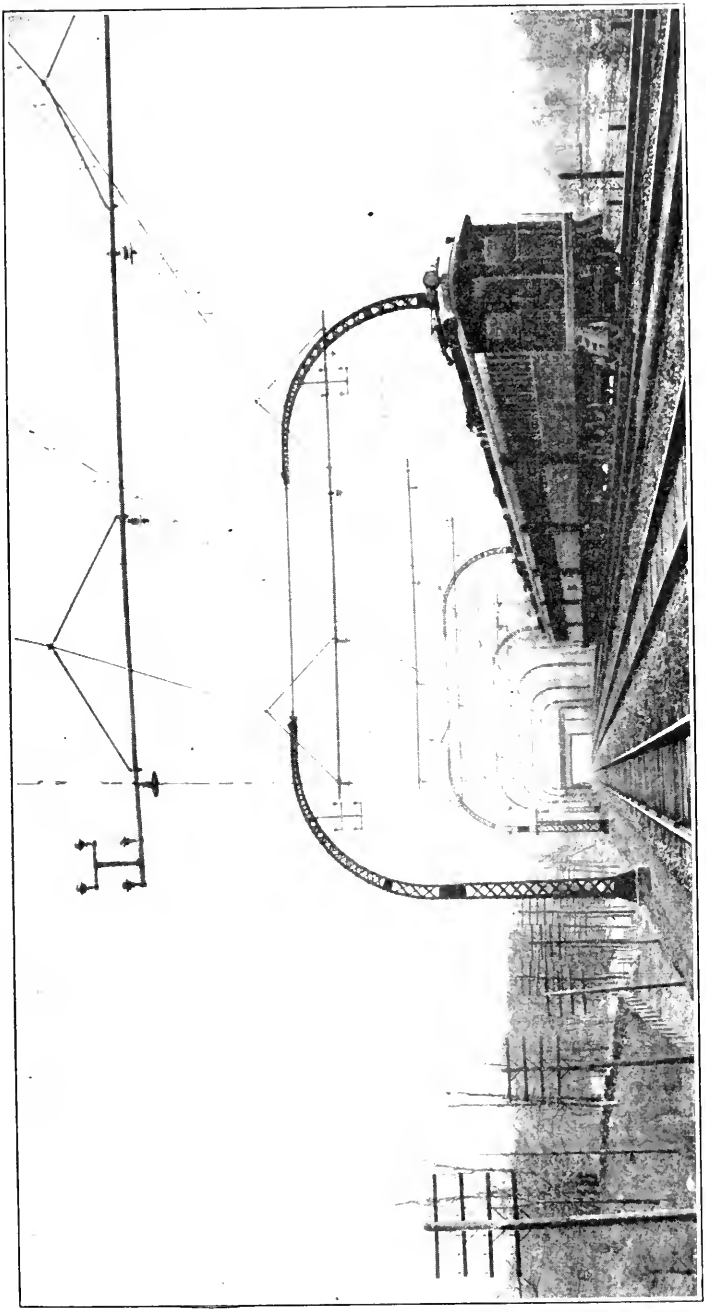


Fig. 2 Multiple Unit Train for Suburban Service; Overhead Construction of New Type Developed by the New York, New Haven and Hartford Railroad

much more extensive plant will afford additional valuable information as to the cost of installation and operation, and the advantages of the three-phase system.

31 The equipment of the power houses which generate the current is essentially similar in the three systems which I have enumerated; but the systems differ in the kind of motors and the auxiliary apparatus for controlling them, and in the methods and apparatus for transmitting the current from the power house to the locomotive or car.

RAILWAY MOTORS

32 Essential requisites in a railway motor are that it shall start its load and quickly accelerate it to the required speed, and that it shall operate continuously at any desired speed, or speeds. Railway conditions make desirable speeds varying from the slowest to the highest schedule speeds for regular operation, both for the movement of freight and passengers, and for making up time.

33 The steam locomotive, which is limited in power by its boiler capacity, is capable of continuous operation at any speed up to the maximum, but the maximum speed in a given case depends both upon the length of the train and the grade of the track. It automatically slows down when ascending a grade, so that the actual horsepower developed does not vary greatly at different speeds. The limitation of the capacity of the electric locomotive is not the power available, as is the case with the steam locomotive, but in the capacity of the motors, and is usually fixed by the heating of their coils. An electric locomotive may safely develop for a short time an output which far exceeds its normal continuous capacity. The power and speed characteristics of electric locomotives therefore differ from those of steam locomotives.

34 The three types of electric motors have certain fundamental differences in speed performance which are important factors in determining the advantages, disadvantages and limitations of the several systems.

THE DIRECT-CURRENT MOTOR

35 The characteristics of the direct-current series railway motor are well known. It automatically adjusts its speed in accordance with the load, running more slowly if the weight of the train be greater, or the grade steeper. The speed with a given load, however, is definite; it is dependent upon the voltage applied to the motor and cannot readily be varied. It is true that the speed can be decreased by

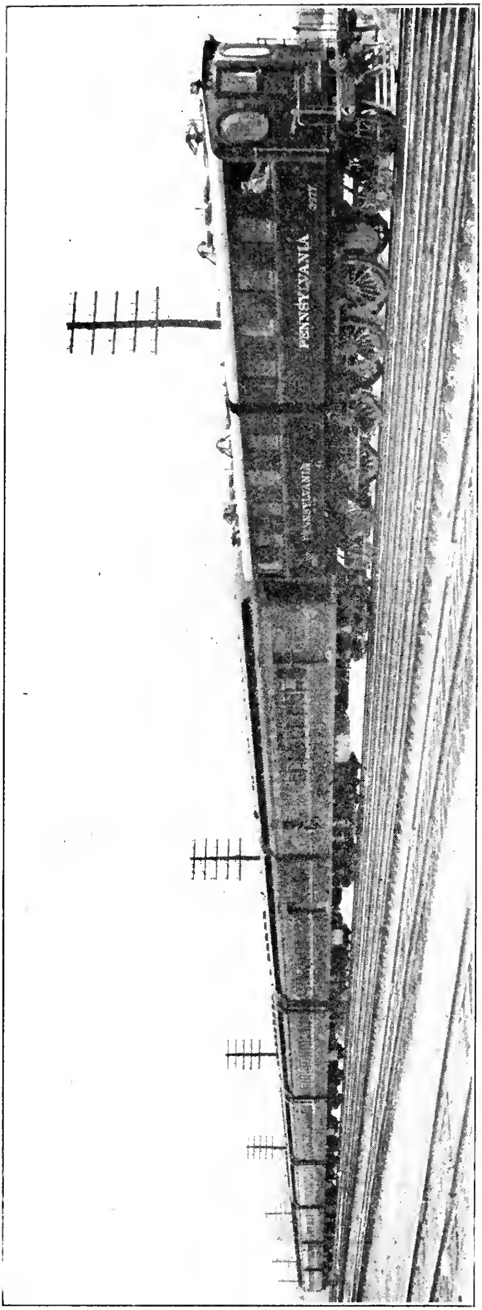


Fig. 3 Pennsylvania Electric Locomotive with all Steel Car Train for Operation into the New York Station

inserting a resistance in the motor circuit, but this is wasteful and is inadmissible except as a temporary expedient. It is true also that the motors may be connected in series, thus dividing the pressure between two motors, and thereby reducing the speed one-half; or if among four motors, to one-quarter speed. As the system of current supply involves a fixed voltage, it is obvious that for emergencies no speeds much above the maximum speed determined in the construction of the motor can be obtained. Furthermore, on account of the high cost involved in maintaining a practically constant voltage throughout the system, the voltage supplied to the motors often decreases considerably at the end of long lines, at the time of heavy load, thereby further reducing the speed attainable. It often happens in railway service that a locomotive should be operated somewhat above the normal speed, and sometimes a locomotive designed for freight service has to be pressed into passenger service. In such cases the speed with the direct-current locomotive would be considerably less than that necessary to maintain the schedule speed. A special form of field control can be used, in certain cases, for varying the speed, although this has so far been utilized to a very limited extent.

THE THREE-PHASE MOTOR

36 On the three-phase system, the motor is inherently a constant-speed motor; it runs at approximately the same speed at light load and at full load; it runs at nearly the same speed up a grade as on level track, although the horsepower required on the grade may be several times that on the level. Conversely, it can run no faster on a level than it can climb a grade. In order to give a lower speed however, the motors may be arranged upon the locomotive in pairs in a manner equivalent to the arrangement of two continuous-current motors in series, just described. Motors may also be arranged for two or more speeds, but this involves some complication in windings and connections. In all cases lower speeds can be secured by the introduction of resistances which increase the losses and lower the efficiency. In no case can the speed in any of the arrangements of motors be appreciably higher at very light load than it is at full load.

37 The motors are of the induction type without commutators and their inherent limitations, and are of relative simplicity in construction. The current is usually supplied at 3000 volts from two overhead lines through two sets of current collectors.

38 With three-phase motors as now constructed and arranged upon locomotives, it is possible with no additional complication so to utilize the motors when locomotives are moving trains upon a descending grade, that they become generators and return current to the line, a feature of value in certain mountainous districts but not of controlling importance in the selection of a universal system.

THE SINGLE-PHASE MOTOR

39 The single-phase railway motor is a series motor with speed characteristics very similar to those of the direct-current motor,

FIG. 4 TYPICAL SECTION SHOWING THIRD RAIL, TRANSMISSION LINE AND SIGNAL BRIDGE OF THE NEW YORK CENTRAL AND HUDSON RIVER RAILROAD

as the speed at a given voltage is greater or less, depending upon the load. The speed with a given load is also greater or less, depending upon the pressure applied to the motor; and this is not limited, as with direct-current motors, to that supplied by the circuit, and to one-half and one-fourth of that pressure, but is capable of adjustment to any desired degree of refinement by means of auxiliary connections from the secondary winding of the transformer on the locomotive, which is necessary for reducing the line voltage of 11,000 volts to the lower voltage required by the motors. Not only may numerous voltages less than the normal be arranged for lower speeds, but higher voltages can be provided to make possible speeds considerably above

the normal. In this simple manner a wide range of efficient speed adjustment is secured which is impossible with other systems.

40 Like the throttle lever of the steam locomotive, the control lever of the single-phase locomotive may be placed in any one of its numerous notches to maintain the required speed. This facility of efficient operation over a wide range of speed and power requirements is one of the especially valuable features of the single-phase system. This difference, however, may be noted: the ability of the steam locomotive to maintain its speed continuously with heavy loads depends upon the capacity of the boiler; on the other hand, the electric locomotive has an ample supply of energy available, drawn from a large power house, and the limit of its endurance is determined by the safe temperature of the motor.

41 The question of determination of the frequency for use on single-phase railways is one of very great importance. Twenty-five cycles is in general use for power transmission purposes and has been adopted by nearly all the single-phase railroads now operating. The Midi Railway of France has adopted 15 cycles. The lower frequency permits of a marked reduction in the size of a motor for a given output, or conversely of a considerable increase in output from a motor of given dimensions and weight. Three-phase installations in nearly all cases employ approximately 15 cycles. The choice of frequency is one of the most involved, difficult and important problems now presented for solution.

SUMMARY

42 Locomotives equipped with each of the three types of motors have been in successful operation and have demonstrated their usefulness, capacity and reliability in practical railway service. The three-phase motor, having a definite constant-speed characteristic, is particularly adapted to certain conditions; but on the other hand it has a less general adaptability to the ordinary varying conditions of railway operation. The single-phase motor has a facility of voltage control which gives an efficient means of speed adjustment, and is in this particular superior to other systems. The relative weights and costs of the several types of motors, and of the locomotives designed to accommodate them, depend upon so many conditions that comparisons must necessarily be general. It will be found, however, that these differences in locomotive cost are in many cases more than offset by the cost of the other elements in the electrical system.

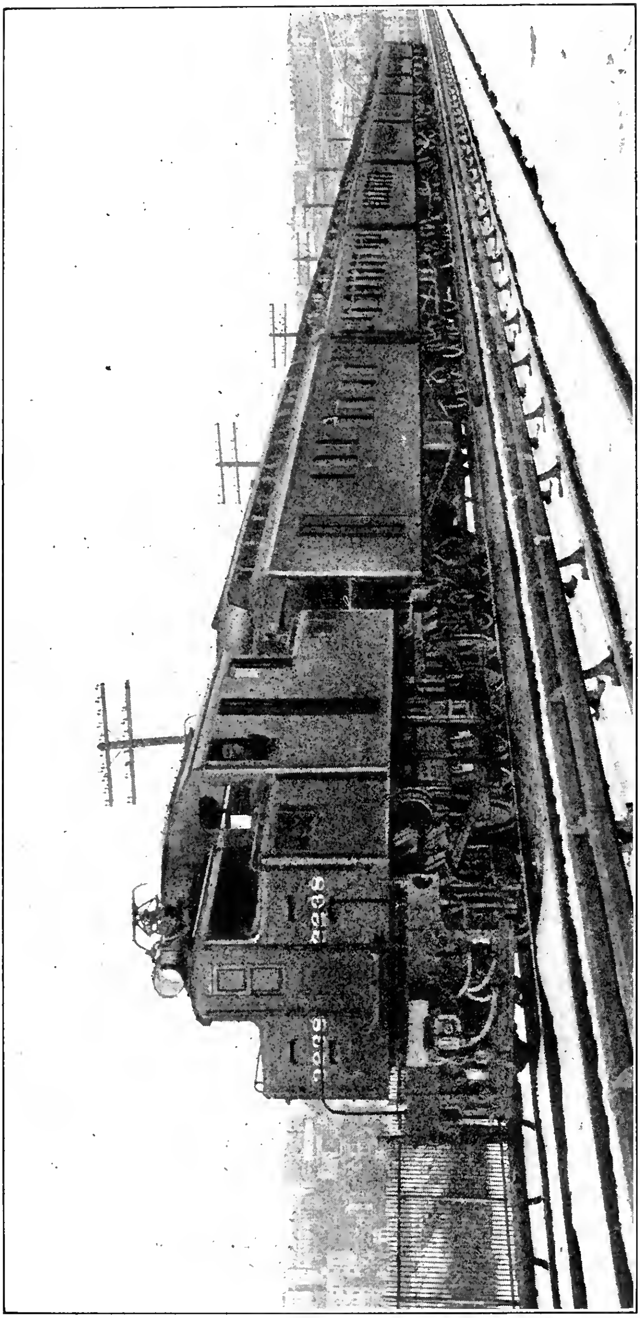


FIG. 5 NEW YORK CENTRAL AND HUDSON RIVER RAILROAD LOCOMOTIVE DRAWING 20TH CENTURY LIMITED TRAIN

43 The control apparatus for all types of locomotives has been developed so that it is reliable and convenient in operation. For each system a small master controller serves to operate by auxiliary means the necessary electric switches for the control of the motors of one locomotive, or to operate simultaneously as a single unit the motors on two or more locomotives or cars in a train.

Transmission of Power from Power House to Locomotive

44 The controlling factor in the cost of electrification in nearly all cases is the system for transmitting power from the power house to the locomotive, and not the locomotive itself. The choice between the several systems must, therefore, be based upon a comparison of the complete systems. The differences between the methods of transmitting power are of far greater importance than the differences between power houses or between locomotives. The current for all systems is generated in usual practice as high-tension alternating current, for the reason that electric energy can be most economically transmitted by high-tension alternating current even though it is in some cases converted into direct current.

45 The transmission systems in use for the three types of locomotives are illustrated in Appendix No. 3. Even a superficial glance at these diagrams brings several points into prominence, as follows:

THE DIRECT-CURRENT SYSTEM

46 For the direct-current locomotive the apparatus which intervenes between the alternating current-generator and the locomotive consists of a number of links or elements through which the electric energy must pass, one after the other. These consist of:

a Raising transformers in groups of three.

b A transmission line of three wires, sub-stations, which require attendance, containing

c Transformers in groups of three, and

d Rotary converters for receiving the alternating current and delivering direct current.

A third-rail contact conductor, which for heavy work must often be supplemented by copper feeders.

f The track return circuit, which must be provided with heavy bonds, and in certain cases supplemented by feeders and so-called negative boosters.

47 It is necessary to maintain the alignment of the third rail within close limits both in its distance from the track rails and in its

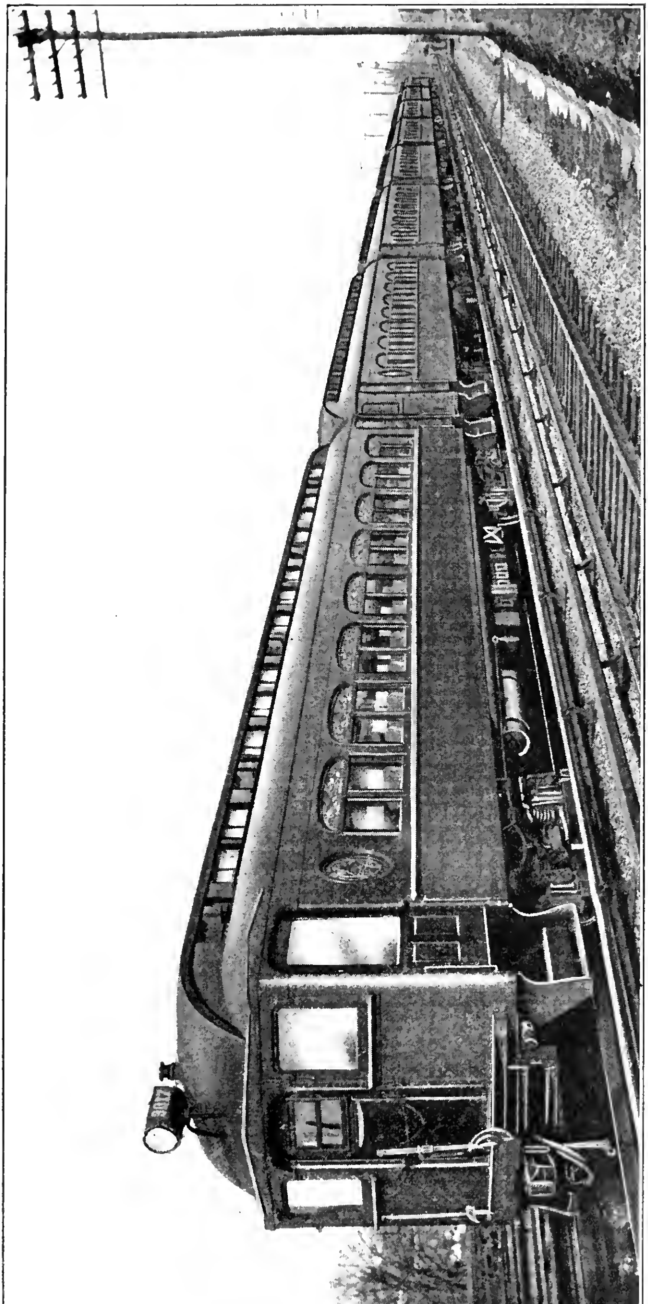


Fig. 6 Multiple Unit Train in Suburban Service on New York Central and Hudson River Railroad

elevation above them, as the contact shoe can have only a small range of automatic adjustment.

THE THREE-PHASE SYSTEM

48 For the three-phase locomotives the respective links between the generator and the locomotives are:

a Raising transformers in groups of three.
b Transmission line of three wires.
c Sub-station transformers in groups of three.
d Two overhead wires as the contact system.
e A track return which usually requires nothing but inexpensive bonding.

49 The two overhead trolley wires require a double system of overhead construction, as the wires must be kept separate and well insulated from one another; the two must be maintained at equal height above the track and at switches and cross-overs the construction is complicated.

THE SINGLE-PHASE SYSTEM

50 For single-phase locomotives there is:

a A raising transformer.
b A transmission line of two wires and sub-stations widely spaced, each containing
c A lowering transformer, which supplies
d A single trolley wire.
e A track return, usually requiring nothing but inexpensive bonding.

51 In certain cases where the distance from the power station is not more than 15 or 20 miles, the single-phase trolley can be supplied directly from the power house, so that only one single element, i.e., the trolley wire, intervenes between the generators and the locomotives.

52 The single trolley wire permits a relatively wide range in height, as the pantagraph trolley automatically adjusts itself to the position of the trolley wire. In some cases the wire has a normal height of 22 ft., but is carried under bridges where the limit is $15\frac{1}{2}$ ft.

53 The three types of railway motors, and the three respective systems for conveying power from the generating station to the locomotives, have all successfully demonstrated their ability to operate railway trains. It is not my purpose to urge the adoption of a particular system, but rather to point out some of the well-known char-

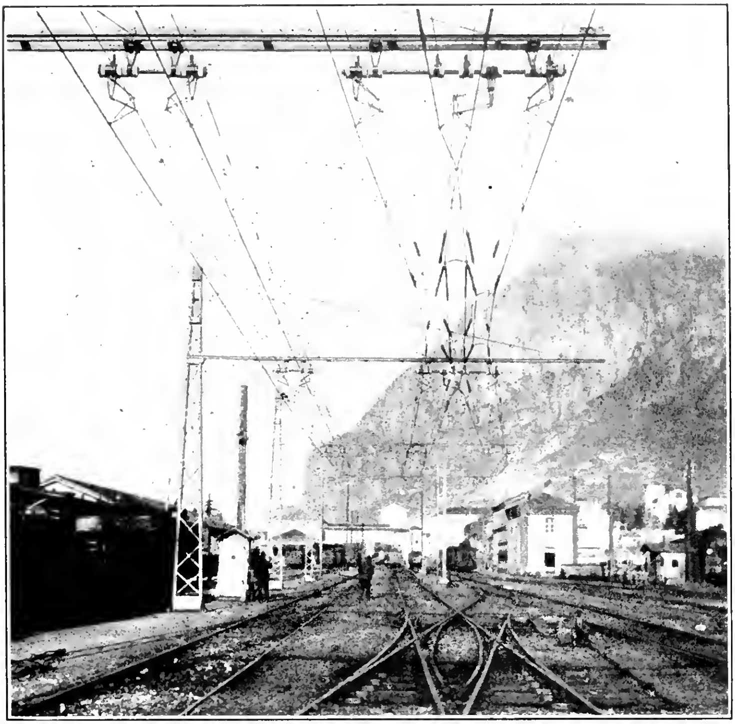


FIG. 7 OVERHEAD CONSTRUCTION ON ITALIAN RAILWAYS, LECCO-CALOLZIO LINE

acteristics of these systems which have a bearing upon their limitations and their general adaptability to railway conditions, and to urge the great gain which will result from a single universal system.

54 As the electrical manufacturing companies with which my name is associated manufacture and install all kinds of direct and alternating-current apparatus, I may be pardoned for saying that I have not permitted my judgment to be influenced by any personal material interests, and that I have treated this subject so as to give others the benefit of a long experience, acquired under circumstances most favorable to ascertaining the facts.

REQUISITES FOR A UNIVERSAL ELECTRIC SYSTEM

55 In selecting a proper electrical system for railway operation, it will probably be generally conceded that the following elements are of prime importance:

a The electric locomotives should be capable of performing the same kinds of service which the steam locomotives

now perform. This will be most readily secured by electric locomotives which can practically duplicate the steam locomotives in speed and power characteristics. This includes a wide range of performance, embracing through passenger service at different schedule speeds; local passenger service; through freight service in heavy trains; the handling of local freight by short trains; and a variety of switching, terminal and transfer movements. This naturally calls for wide variation in tractive effort and in speed, both for the operation of different kinds of trains, and also for the operation of the same train under the varying conditions usually incident to railway service.

The electric locomotive should be capable of exceeding the steam locomotive in its power capacity. It should be able to handle heavier trains and loads, to operate at higher speeds, and in general to exceed the ordinary limits of the steam locomotive in these regards. The readiness with which several electric locomotives can be operated as a single unit enables any amount of power to be applied to a train.

c The electric system should adapt itself to requirements beyond the ordinary limitations of the steam locomotive in small as well as large things. It should be adapted for use on branch lines, and for light passenger and freight service similar to that so profitably conducted by interurban electric roads, which in many cases run parallel to steam roads, not only taking away the traffic of the steam roads, but building up a new and highly profitable traffic, both in passenger and in express service.

d A universal electrical system requires that power should be transmitted economically over long distances and supplied to the contact conductor. The system should utilize the most highly perfected apparatus for the electric transmission of energy and its transformation into suitable pressures for use.

e The contact conductor in an ideal system should be economical to construct, both for the heaviest locomotives where the traffic is dense, and for light service on branch lines. It should impose minimum inconvenience to track maintenance; should give minimum probability of disarrange-

ment in case of derailment, or in case of snow and sleet, and should in general be so placed and constructed as to give a maximum assurance of continuity of service.

56 The use now made of electricity in steam railway service has been brought about, generally speaking, through compulsion. The steam locomotive has reached its limitations and has been found unsuitable and inadequate in tunnels or in terminal service. Even where other considerations may have been controlling, the problem has usually been a specific one of electrifying a relatively small area. The problem has been solved by considering those factors which were of immediate importance, without giving weight to uniformity with other systems or of extension.

57 Now the natural course of development will be the extension of these limited zones, until after a time they meet. Then there will arise great inconvenience and expense if the systems are unlike. For the present it may be a matter of little moment whether different systems have their contact conductors in the same position, or whether the character of the current used is the same or different. As previously stated, in the early days of railroading, it was of little consequence whether the tracks of the different systems in various parts of the country were alike or unlike, but later it did make a vital difference, and the variation resulted in financial burdens which even yet lie heavily on some railways. It is this large view into the future of electrical service which should be taken by those responsible for electric railway development.

THE FUTURE OF ELECTRIFICATION OF RAILWAYS

58 The complete electrification of a railway will necessitate a rearrangement of ideas and practices in regard to operations. Coaling and watering places will not be needed; passenger trains will be differently composed, some classes being of less weight; and they will operate more frequently, thus promoting travel; other trains will be heavier than at present, or will operate at higher speeds; and branch lines, by the use of electrically fitted cars, can be given a through service not now enjoyed.

59 The movement of freight will undergo great changes, due to the fact that electric locomotives can be constructed with great excess capacity, enabling them to move longer trains at schedule speed on rising gradients.

60 The large percentage of shunting operations due entirely to the use of steam locomotives will no longer be required.

61 The railway companies can combine upon some coöperative plan for the generation of electricity, thereby effecting large savings in capital expenditures; and can utilize their own rights of way for the transmission of the current, not only for the operation of trains but for many other useful purposes.

62 Notwithstanding the fact that great strides have already been made in cheapening the cost of generating electricity by steam engines, I foresee, from the progress made in the development of gas and oil engine power, a still further reduction in cost which will accelerate the work of electrifying existing railways.

63 One important aspect of this great question will engage the thoughtful consideration of every government, namely, the military necessity for uniform railway equipment in time of war.

64 There will be serious difficulties to surmount in the selection of a general system. There naturally will be arguments in favor of one or another of the systems now in use and the inclination of those who have adopted a particular system to advocate its general use. There will be enthusiastic inventors, and there will be many advocates of the common view, namely, that there is room for several systems and that each system will best meet the requirements of a particular case. There will be those who give undue weight to some feature of minor importance, such as a particular type of motor or of locomotive, instead of giving a broad consideration to the whole system, and recognizing that, in the general problem of railway electrification, facility and economy in transmitting power from the power house to the locomotive, are of controlling importance.

65 Were there now only one system to be considered, there would be a concentration of the energy of thousands on the perfecting and simplifying of the apparatus for that system, to the advantage of railway companies and of manufacturers.

66 In conclusion, I can only repeat, and earnestly recommend to the serious consideration of railway engineers and those in authority, the pressing need of determining the system which admits of the largest extension of railway electrification and of a prompt selection of those standards of electrification which will render possible a complete interchange of traffic in order to save expense in the future and to avoid difficulties and delays certain to arise unless some common understanding is arrived at very shortly.

APPENDIX NO. 1

THE SINGLE-PHASE SYSTEM ON THE NEW YORK, NEW HAVEN & HARTFORD RAILROAD

The most important installation of single-phase apparatus is that of the New York, New Haven & Hartford Railroad, leading out of New York City. Practically all the railroad service between New York and Boston, as well as the New England states, is over the four tracks of this railroad. The trains pass into the Grand Central Station in New York City over the lines of the New York Central & Hudson River Railroad, which is electrically equipped with the third-rail system for operation by direct current at 650 volts. Selection of the system for the New Haven railroad was restricted by the necessity of operating the New Haven trains over the New York Central tracks; but the decision was in favor of the single-phase system, notwithstanding the limitation that the locomotives must operate successively both by single-phase current and direct current.

102 The trains of the New Haven system leaving the Grand Central Station pass over 12 miles of the tracks of the New York Central system, operating from the third rail by direct current. They then pass to the New Haven tracks at full speed, receiving alternating current at 11,000 volts from the overhead trolley wires which extend 21 miles to Stamford, a total distance of 33 miles from New York, this being the end of the initial installation of the single-phase system.

103 The power house is located near the Stamford end of the electrified section and contains four 11,000-volt turbo-generators having an aggregate capacity of over 16,000 kw. The current passes directly from the generators to the trolley wires, as illustrated in Fig. 18 and in the last diagram of Fig. 19.

104 The overhead trolley system consists of a steel contact trolley wire suspended every 10 ft. from a copper trolley wire, which in turn is suspended at intermediate points from two steel catenary cables by triangular-shaped hangers. These cables are supported upon insulators resting upon steel bridges spaced at distances of 300 ft. along the right of way. The construction is shown in Fig. 1 of the paper.

105 As in general there are four tracks and in some cases more, the comparatively light steel bridges are made to span the right of way and to carry as many sets of the trolley conductors as there are tracks. Stronger bridges to which the catenary cables are anchored are located about every two miles. At certain points these anchor bridges are utilized for supporting the block signals and also to carry oil circuit breakers which permit the trolley wires to be sectionalized for service operation or in emergencies. Normally all the trolley wires and the supporting cables over all the tracks are connected together electrically and also to the source of supply at the power house.

106 There are 41 locomotives in regular operation, and also four motor cars with six trail cars operating on the multiple unit system in suburban service. The alternating current is taken from the overhead trolley wire by a pantagraph which presses a shoe against the wire. The direct current on the New York Central zone is obtained from the third rail by means of ordinary sliding contact shoes. Both the pantagraph and the contact shoes are manipulated by compressed air. The locomotive is described in Par. 203.

107 For reasons of economy in operation the locomotives were built under the requirement that each should be capable of hauling a 200-ton train from New York to New Haven, making all station stops in accordance with the regular schedules, or an express train of 250 tons, and that the locomotives should be so arranged that two or more could be operated by a single engineer for the movement of heavier trains. The particular size selected permits about 75 per cent of the trains to be operated by a single unit.

TABLE 1 RECORD OF SINGLE-PHASE SERVICE

NEW YORK, NEW HAVEN & HARTFORD RAILROAD FOR 12 MONTHS

	Total Miles Run	No. Locomotive Delays	Miles Run per Locomotive Delay	No. of Power House Delays	No. of Line Delays
1909					
April	146,189	9	16,243	..	3
May	155,551	25	6,222	1	3
June	166,759	14	11,911	.	4
July	183,434	13	14,110	..	2
August	177,714	14	12,694	.	5
September	189,656	14	13,547	..	1
October	174,400	11	15,854	1	4
November	173,370	10	17,337	..	1
December	167,808	23	7,296	..	3
1910					
January	163,274	28	5,831	..	2
February	138,929	12	11,577	..	1
March	156,901	12	13,075	..	1

108 During the past year, the electric service has surpassed in efficiency all records previously obtained on this division with steam locomotives. The actual figures are given in Table 1, which covers the movement of passenger trains over the 12 miles of third-rail operation and 21 miles of single-phase operation, for which 41 locomotives, that have been used from 22 to 33 months, were available.

109 The early fears as to difficulties in commutation have been dispelled by the records of performance, as many of the motors have operated over 100,000 miles without turning or even sandpapering the commutators, and the brushes show an average life of 40,000 to 45,000 miles.

110 The average number of miles run per locomotive delay during the year exceeds 12,000, equivalent to a dozen trips between New York and Chicago, or thirty trips between London and Glasgow.

111 The locomotive delays (many of which only slightly exceeded one minute duration) include not only those from electrical causes, but from mechanical

defects as well, such as loose tires, burst airhose, hot journal boxes, frozen steam hose, etc. A comparatively large number of delays in December and January were due to the very severe weather and the unusual amount of snow and ice. These locomotives have been making regularly an average of about four and one-half trips of 33 miles per day, hauling trains 25 to 50 per cent heavier, or even more in the case of express trains, than the locomotives were guaranteed to handle. Most of the locomotives have run about 100,000 miles, but there is seldom more than one (which is 2½ per cent of the whole number), out of service for repairs, a record said by the officials of the company to be much better than for the steam locomotives which were replaced. These officials also say that the cost of maintenance per mile and the number of miles run per electric locomotive are far more favorable than with steam locomotives, even with the present very short run of 33 miles.

112 The cost of maintenance of the distribution system is relatively small compared with that of the low-voltage third-rail system. The delays due to the transmission lines and overhead construction, though few in number, include those brought about by extraordinary conditions, such as steam from switch engines and by wrong operation of switches.

113 The heaviest traffic on the New York division of the New Haven road, and the occasion on which delays would be most deplored, is on the day of the annual intercollegiate football game at New Haven. The service on this day for 1908 and 1909 was as follows:

	1908	1909
Regular trains	128	126
Special trains	30	29
Total trains	158	155
Number of train delays	2	0
Total duration of delays	17 min.	

114 In considering the capability of the single-phase system for continuous performance, the record of the six single-phase locomotives in service at the St. Clair Tunnel of the Grand Trunk Railway is worthy of mention. These locomotives have now been running two years and have made about 70,000 miles each, averaging about 100 miles per day, or 25 trips of 4 miles. It has not been necessary to use a steam locomotive since the regular electric service was started (May 1908) and during the last 12 months the service has been responsible for but one train delay, of eight minutes. The locomotive is described in Par. 204.

APPENDIX NO. 2

DATA ON ELECTRIC LOCOMOTIVES OF AMERICAN DESIGN

The locomotives on which data are given were built for heavy railway service. They are for passenger service and for combined passenger and freight, and include locomotives for direct current, three-phase current, and single-phase alternating current, and others adapted for operation on either single-phase alternating current or direct current.

202 A brief description of these locomotives follows, including mention of some of their notable features.

LOCOMOTIVES OF THE WESTINGHOUSE ELECTRIC & MFG. CO.

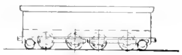
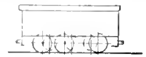
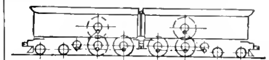
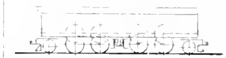
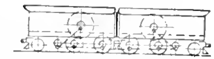
203 Referring to Table 2, the first column covers locomotives built for the New York, New Haven & Hartford Railroad, for operation on their electrified zone between New York and New Haven. The electrical system demanded that the locomotives be capable of operation both on single-phase and direct current. There are 41 of these locomotives in operation. A gearless concentric motor for each driving axle is mounted on a quill flexibly connected to the driving wheels. The dead weight on the axles is thus reduced to a minimum. Two of these locomotives are shown attached to the train in Fig. 1 of the paper.

204 The second column covers locomotives built for the Grand Trunk Railway for operation in the St. Clair Tunnel under the St. Clair River. These locomotives are designed for operation with single-phase current only. They are handling the entire freight and passenger traffic through the tunnel. A report of the operation of these locomotives is given in the last paragraph of Appendix No. 1. The locomotive is shown in Fig. 8.

205 The third column covers locomotives built for the Pennsylvania Railroad for operation in their New York tunnel. They are for passenger service only and operate on direct current at 600 volts on the conductor. The first locomotive has been run 17,000 miles on test. The center of gravity of these locomotives is high, as the motor is mounted well above the driving axles. The transmission from motor to wheels is by cranks and connecting rods. These parts are protected from possible damage due to short circuit by interposing between the armature and its shaft a friction clutch which will slip before damaging stresses are imposed on the transmission. The motors are the largest railway motors ever built and are provided with commutating poles, making possible the use of a shunted field control which is applied to these locomotives. The locomotive is shown in Figs. 9 and 10.

206 The fourth column covers a locomotive built for the New York, New Haven & Hartford Railroad for use in high speed freight and medium-speed passenger service. It also is fitted for operation both with single-phase and direct current.

TABLE 2 DATA ON ELECTRIC LOCOMOTIVES OF AMERICAN DESIGN
BUILT BY THE WESTINGHOUSE ELECTRIC & MFG. CO.

					
Built for	New Haven	Grand Trunk St. Clair Tunnel	Pennsylvania	New Haven	New Haven
Electric system	A.C., D.C.	A.C.	D.C.	A.C., D.C.	A.C., D.C.
Service	Passenger	Frt. & Pass.	Passenger	Frt. & Pass.	Frt. & Pass.
First placed in service	July 1907	February 1908	17,000-mile test	3000-mile test	building
No. in service or on order May 1910	41	6	24	1	1
No. motors per locomotive	4	3	2	4	2
Armature diameter, inches	39½	30	56	39½	76
Core length, including vent openings, inches	18	14¾	23	13	13
Weight one motor, pounds	16,420	15,660	45,000	19,770	41,600
Weight all motors on locomotive	65,680	46,980	90,000	79,080	83,200
Weight all electrical parts	110,400	58,400	127,200	130,000	135,000
Weight all mechanical parts	94,100	73,600	204,800	130,000	125,000
Weight complete locomotive	204,500	132,000	332,000	260,000	260,000
Weight on driving wheels	162,000	132,000	207,800	180,000	180,000
Weight complete locomotive for A.C. operation	196,000	132,000	D.C.	241,000	240,000
Max. guar't'd speed, miles per hr.	about 86	30	about 80	45	45
Feature limiting speed	track	armatures	connecting rod	armatures	armatures
Max. tractive effort	19,200	43,800	69,300	40,000	40,000
Loco. wt. in excess of 18% adhesion Max. T.E., A.C. operation	88,700	none	none	18,500	17,500
Designed for trailing load, tons	250	500	550	1500 freight 800 pass.	1500 freight 800 pass.
Balance speed on level with above load	about 75	about 25	60	35 freight 45 pass.	35 freight 45 pass.

It has been run approximately 3000 miles in test service, actually hauling regular freight trains, including the steam locomotives, over the electrified section of the railroad on the normal schedules for the movement of these trains. A pinion at each end of the motor meshes with a flexible gear whose center is rigidly secured to the quill surrounding the axle, the flexible gear overcoming the difficulties in securing tooth alignment and division of load which are liable to occur when rigid twin gears are used. It is the only electric locomotive equipped with spur-geared motors which are bolted rigidly to the spring-supported parts of the locomotive. Each driving wheel is driven through helical springs, the arrangement being such that the driving wheel has practically free vertical play. The locomotive has two trucks, the draw-bar pull being transmitted

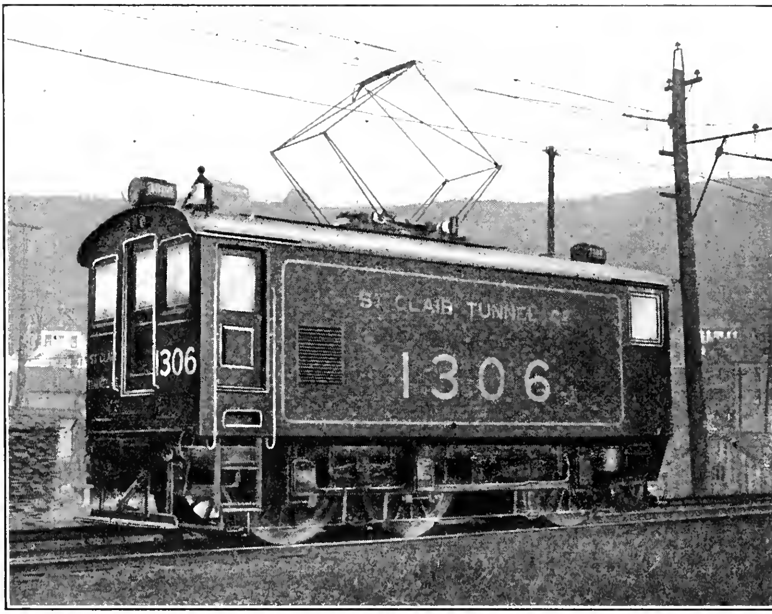


FIG. 8 SINGLE-PHASE LOCOMOTIVE FOR PASSENGER AND FREIGHT SERVICE IN ST. CLAIR TUNNEL OF GRAND TRUNK RAILWAY

through the truck frames. The body is spring-mounted on friction plates in place of being carried on truck center pins in the usual manner. It is an exceptionally easy riding machine with very low rolling friction. The performance has b en satisfactory, and a speed of 40 miles per hour was attained on level track with a 1600-ton train. See Figs. 11 and 12.

207 The fifth column covers a locomotive for the same railroad and service as that just described. The comparison between geared and connecting-rod motors for identical service is a very interesting feature of this development. The weights given in both the fourth and fifth columns are those on which locomotives of these types would generally be built. The actual locomotives are somewhat

heavier, due to particular features of design not inherent in the type. The effect on the connecting rods and pins of the pulsating torque of a single-phase current is avoided by the introduction of a flexible connection between the armature and its shaft. This locomotive has not been tested.

208 These last two locomotives were ordered by the New Haven road to demonstrate the practicability of electric traction for freight service and to assist in determining the most suitable kind or type of locomotive.

LOCOMOTIVES OF THE GENERAL ELECTRIC COMPANY

209 The first column of Table 3 covers locomotives built for the New York Central & Hudson River Railroad for operation on the electrified zone of the New York City terminal. Forty-seven of these locomotives are in use, the first having been put in operation in July 1906. They are used for passenger service only, and operate on direct current at 600 volts. The mechanical equipment of this locomotive consists of a main driving wheel base with four driving axles and a four-wheel guiding truck at either end. The motor is of the bi-polar gearless type, the armature being mounted directly on the driving axle, and the mechanical structure of the locomotive forming a portion of the magnetic circuit of the motors. The characteristic feature of the locomotive is the simplicity of its electrical and mechanical construction, which contributes to its high efficiency and low maintenance cost. The locomotive is shown in Figs. 5 and 13.

210 The second column of Table 3 covers locomotives built for operation at the Detroit River Tunnel. These are to be used for both freight and passenger service between Detroit, Mich., and Windsor, Ont., and will be operated at 600 volts, direct current. The running gear consists of two trucks connected together with a massive hinge so as to form a single articulated wheel base, and buffers carried on the outer end frames of the trucks. The motor is of the direct-current geared type with commutating poles and is interesting as the first application of the commutating pole motor to this class of service. Twin gearing is used between the motor and driving axle, and consists of a pinion at each end of the armature shaft and a corresponding gear on the axle. The use of twin gearing relieves the armature shaft of torsional strains and maintains the parallelism of the shaft and axle. Five of these locomotives have been built and are awaiting completion of the tunnel. While they are not in actual operation, extensive tests made on a test track in hauling and accelerating freight trains up to 1500 tons in weight have proved that this type is very satisfactory for the service.

211 The third column covers locomotives built for the Baltimore & Ohio Railroad for operation of both freight and passenger service through the Baltimore Belt Line Tunnel. Two of these locomotives are in use and operate on direct current at 600 volts. The general design is similar to the Detroit Tunnel locomotive described above and the same type of motors are used, but the motors are geared for higher speed in order to meet the speeds required by passenger service on the relatively lighter grades of the Baltimore Tunnel.

212 The fourth column covers locomotives built for the operation of freight and passenger trains through the Cascade Tunnel of the Great Northern Railway. These locomotives are designed for three-phase operation at 25 cycles and 6600 volts on the trolley. The mechanical structure consists of an articulated wheel base similar to that of the Detroit River Tunnel locomotive described above. The a motor is three-phase induction motor with external secondary resistance and

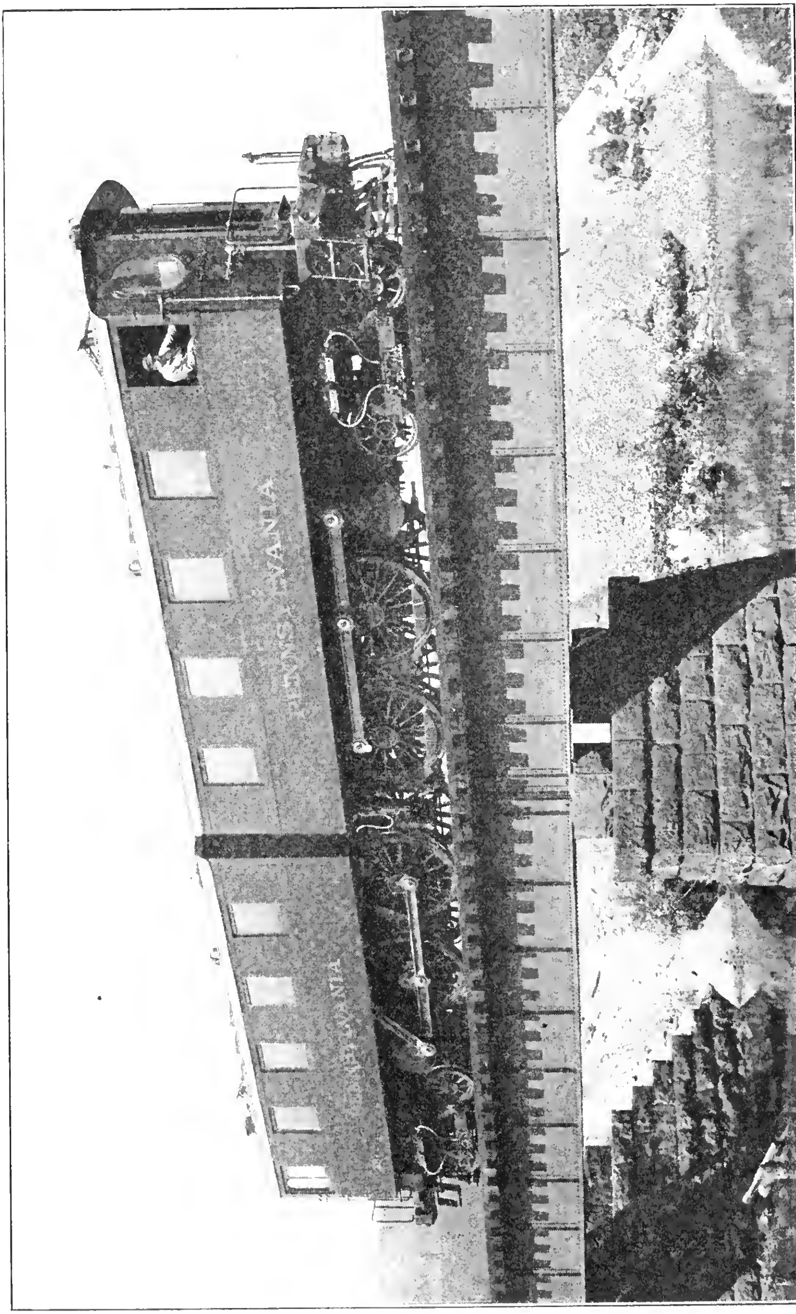


FIG. 9 PENNSYLVANIA DOUBLE ARTICULATED LOCOMOTIVE FOR THE NEW YORK TUNNEL SERVICE

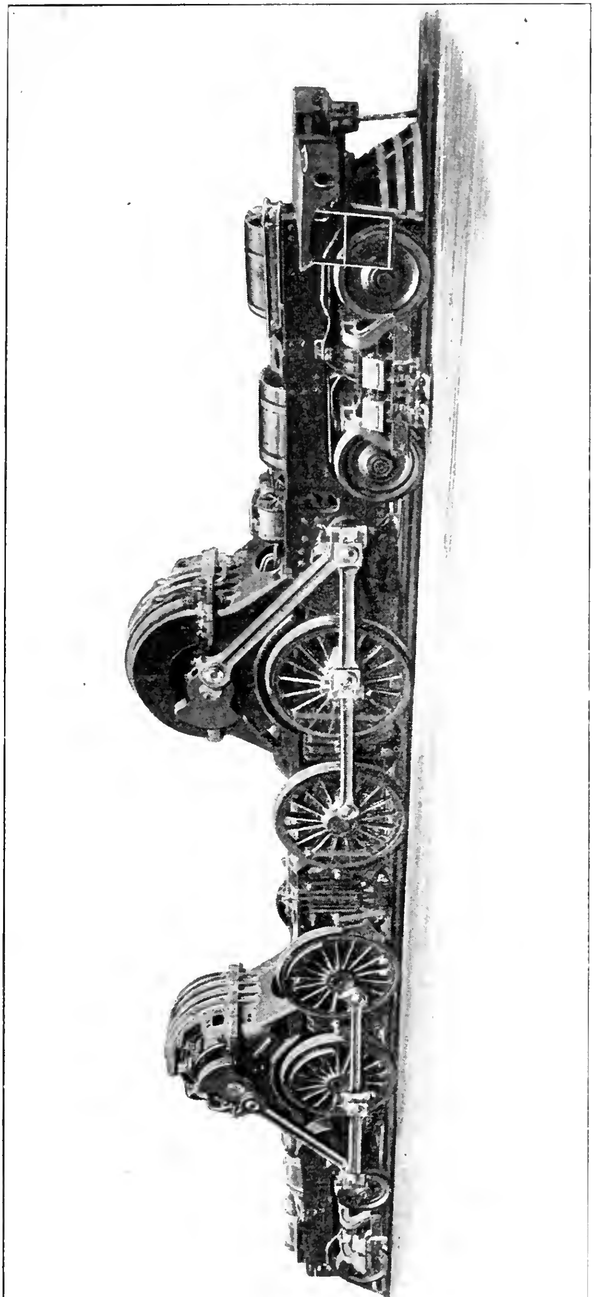


Fig. 10 Under Frames, Motors and Driving Mechanism of Pennsylvania Double Articulated Locomotive for New York Tunnel Service

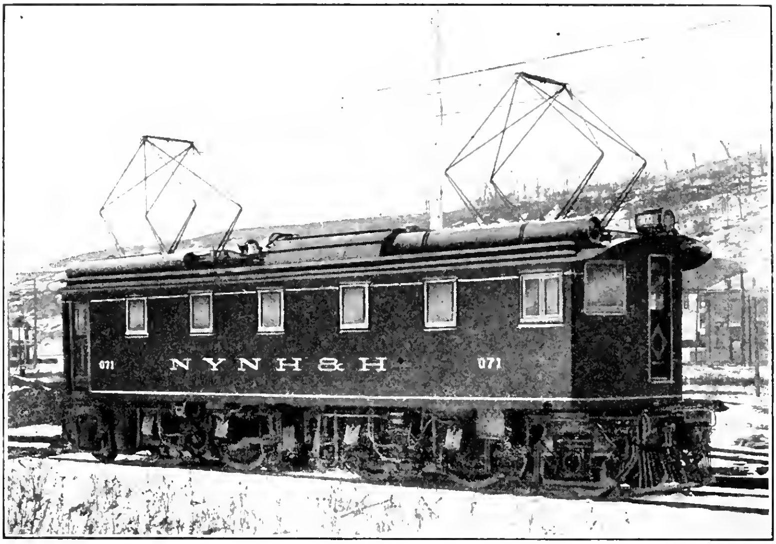


Fig. 11 Single-Phase and Direct-Current Locomotive for Passenger and Freight Service on the New York, New Haven & Hartford Railroad

MOTORS WITH FLEXIBLE TWIN SPUR GEARS ARE PLACED DIRECTLY OVER DRIVING AXLES

fitted with a gear at each end of the armature shaft. The service for which they are ultimately designed is the operation of a division 57 miles long with ruling

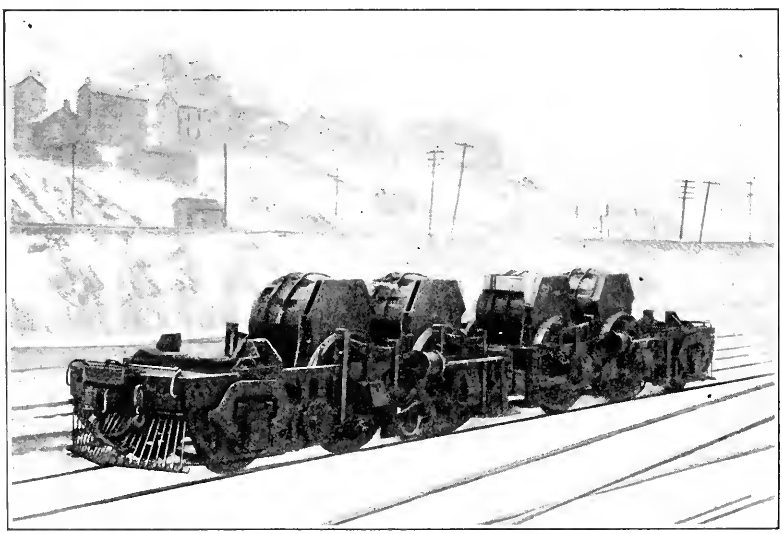
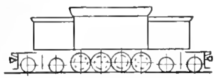
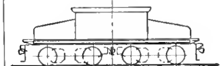
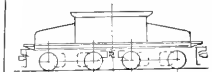
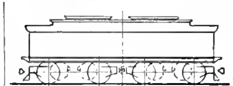
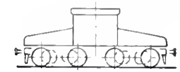


Fig. 12 View Showing Arrangement of Motors over Driving Axles for Locomotive Illustrated in Fig. 11

TABLE 3 DATA ON ELECTRIC LOCOMOTIVES OF AMERICAN DESIGN

BUILT BY THE GENERAL ELECTRIC COMPANY

					
Built for	N. Y. C. & H. R. R.	Detroit River Tunnel	B. & O. R. R.	Great Northern	Paris-Orleans
Electric system	D.C.	D.C.	D.C.	3-phase	D.C.
Service	Passenger	Frt. & Pass.	Frt. & Pass.	Frt. & Pass.	Passenger
First placed in service	July 1906	tests completed	March 1910	July 1909	1899
No. in service or on order May 1910	47	6	2	4	11
No. motors per locomotive	4	4	4	4	4
Armature diameter, inches	29	25	25	35¾	23½
Core length, including vent. opening, inches	19	11½	11½	16¼	12
Weight one motor, pounds	18,150	10,560	10,560	15,000	8,855
Weight all motors on locomotive	72,600	42,240	42,240	60,000	35,420
Weight all electrical parts	91,200	54,000	54,000	109,000	42,500
Weight all mechanical parts	138,800	146,000	130,000	121,000	67,500
Weight complete locomotive	230,000	200,000	184,000	230,000	110,000
Weight on driving wheels	141,000	200,000	184,000	230,000	110,000
Weight complete locomotive for A.C. operation	D.C.	D.C.	D.C.	230,000	D.C.
Max. guar't'd speed, miles per hr.	75	30	55	30	45
Feature limiting speed	track	armature	armature	armature	armature
Max. tractive effort	47,000	67,000	61,000	77,000	37,000
Loco. wt. in excess of 18% adhesion Max. T.E., A.C. operation	none	none	none	none	none
Designed for trailing load, tons					
Freight		900 on	850 on	500 on 2.2% grade	
Passenger		600 2% grade	500 1½% grade		
Balance speed on level with above load	435 / 63	Freight 20.5 / Pass. 22	Freight 26 / Pass. 30	15	300 / 32

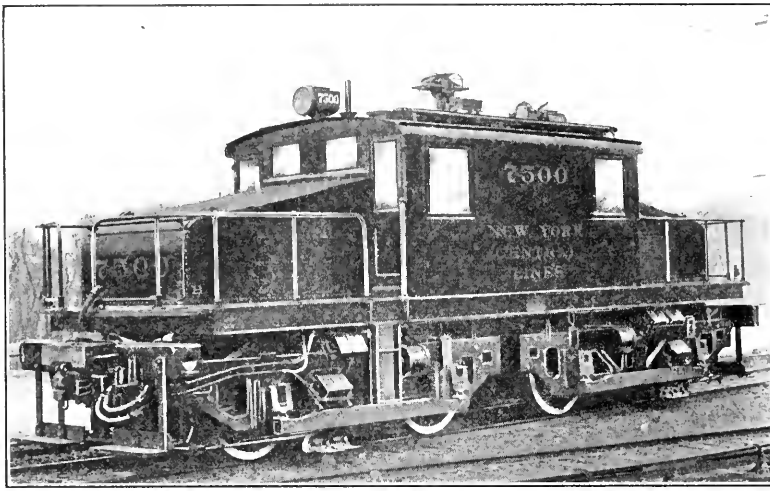


FIG. 13 ELECTRIC LOCOMOTIVE ON THE NEW YORK CENTRAL & HUDSON RIVER RAILROAD

grades of 2.2 per cent and an average grade of 1.55 per cent. Four of these locomotives are in service and it may be of interest to note that they were involved in the disastrous avalanche of March 1, 1910, which swept through the electrified yards at Wellington, Wash. The locomotive is shown in Fig. 14.

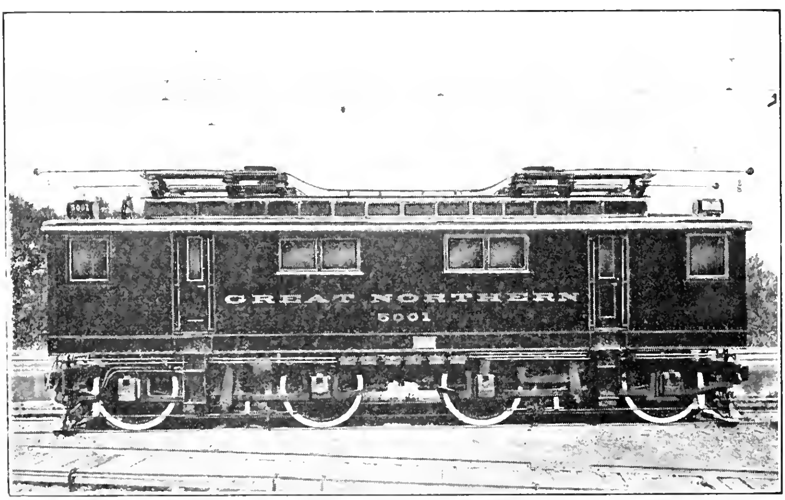


FIG. 14 ELECTRIC LOCOMOTIVE ON THE GREAT NORTHERN RAILWAY

213 The fifth column covers locomotives built for the Paris-Orleans Railway, for use in hauling passenger trains from the Austerlitz Station to the Quai d'Orsay. They are designed for operating on 600 volts, direct current. These locomotives are historically of interest, the first one of them having been delivered in 1899, and twelve being now in service. Each locomotive has two independent trucks, each truck equipped with two geared motors, and carrying weight of cab and platform on the center pin with draft gear and buffer attached to this platform. This represents a type of locomotive of which a large number have been built, and which has proved highly satisfactory for light and medium classes of service.

APPENDIX NO. 3

COMPARISON OF SYSTEMS OF ELECTRIFICATION

The salient features of the three systems of railway electrification are presented in a number of diagrams so arranged as to permit of a ready comparison between their essential characteristics, particularly in the circuits and apparatus which transmit the power from the power station to the locomotive.

302 The perspective sketches, Figs. 15 to 18, show the commonly used types of apparatus and circuits in a simple and elementary way, as only a single generator and a single sub-station, containing but one group of units, are shown, and auxiliaries such as switchboard apparatus are altogether omitted.

303 Fig. 15, showing the direct-current system, illustrates the alternating-current generator, the three raising transformers, the three-phase transmission circuit, the three sub-station lower transformers, and the rotary converter which supplies direct current to the third-rail contact system.

304 Fig. 16, illustrating the three-phase system, is similar to Fig. 15 up to the point where the power passes the sub-station transformers. Power is then delivered directly to the contact system, consisting of two overhead trolley wires, shown suspended from supporting cables in accordance with the commonly used catenary construction.

305 Fig. 17, presenting the single-phase system, has a similarity to the preceding sketch of the three-phase system, Fig. 16, and may be derived from it by simplifying its several elements. Single transformers instead of groups of three are found in the power house and sub-station. The transmission has two wires instead of three and there is but one trolley wire instead of two.

306 Fig. 18 shows the single-phase system where the distances are moderate and the generator can supply current directly to the trolley wire at 11,000 volts, thereby eliminating the high-tension transmission circuit and the sub-stations. This is the method employed in the single-phase installation on the New Haven system.

DIAGRAMS OF TRANSMISSION CIRCUITS AND SUB-STATIONS

307 Fig. 19 shows the arrangement of transmission lines and contact circuits and the relative number and location of sub-stations for each of the three systems.

308 The direct-current sketch, Fig. 19, shows the three-phase transmission line running from the power house to the sub-stations, which contain step-down transformers and rotary converters for changing the high-potential alternating current to low-potential direct current. It also shows the third rail supplemented by an auxiliary conductor or feeder. The track serves for the return circuit.

309 In a certain typical case it was found that the sub-stations should be approximately eight miles apart for a pressure of 600 volts in the direct-current system. If direct current were used at a pressure of 1200 volts, half of the sub-stations could be omitted.

310 The distances above mentioned are found to be proper for a particular case and the diagram is intended simply to show approximately the relative number of sub-stations required in the several systems. The actual distances in other cases may be more or less than those given. In the several systems employing a transmission line the distance may obviously be extended to include a greater number of sub-stations than are shown.

311 The three-phase sketch, Fig. 19, shows the three-phase transmission line and sub-stations containing transformers only, for reducing the high-potential alternating current to low-potential alternating current for use on the double overhead trolley system with track return. The sub-stations are spaced the same distance apart as those in the direct-current system. This arrangement of sub-stations is for 3300 volts on the trolley. With 6600 volts on the trolley, half of the sub-stations would be omitted.

312 The larger single-phase sketch, Fig. 19, shows a single-phase transmission line running to sub-stations containing transformers only, to reduce the high-potential alternating current of transmission to a suitable potential, 11,000 volts, for use on the single overhead trolley with track return.

313 The smaller single-phase sketch shows a single-phase line which is not too long to prevent the entire system from being fed directly from the generators without the intervention of transmission line or transformers between the generators and the trolley circuit. This sketch shows the method employed on the New Haven system.

314 In thickly populated districts congested with traffic, the generating stations, of which there should be not less than two in order to minimize interruptions to traffic, should probably be located at junction points or places demanding the greatest power and at distances not exceeding thirty or forty miles. With such a disposition of power houses, the overhead trolley wires will usually be sufficient for the supply of current. In like manner, where the traffic is not so heavy, the power houses can be placed at greater distances, bearing in mind, however, that the increase in traffic may subsequently demand intermediate power houses or sub-stations. In cases where power stations are long distances apart, the single trolley wire should probably be supplemented by an additional circuit in order to guard against interruptions due to defect in the trolley wire, and to give a sufficient supply of power for any contingency.

COMPARATIVE LOSSES, SHOWN IN FIG. 20

315 Fig. 20 shows the comparative losses between the generators and the locomotives for each of the three systems, based on a class of service where the input to the locomotives by the several systems is practically the same.

316 As some kinds of service render one type of motor with its auxiliary apparatus and control more efficient, while under other conditions it may be less efficient, this variable element has been eliminated by assuming the same power delivered to each locomotive as a basis for a general comparison of the transmission losses.

317 The total height of each column in the diagram indicates the total power delivered by the power house in the system designated. The height of the long portion at the lower part of each column indicates the amount of power which reaches the locomotive.

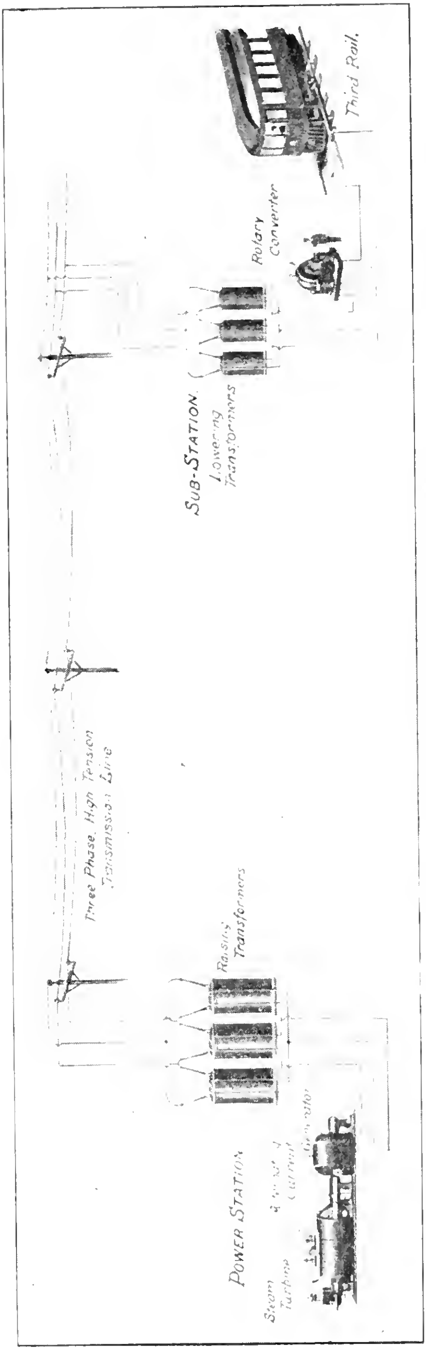


FIG. 15 DIRECT-CURRENT RAILWAY SYSTEM

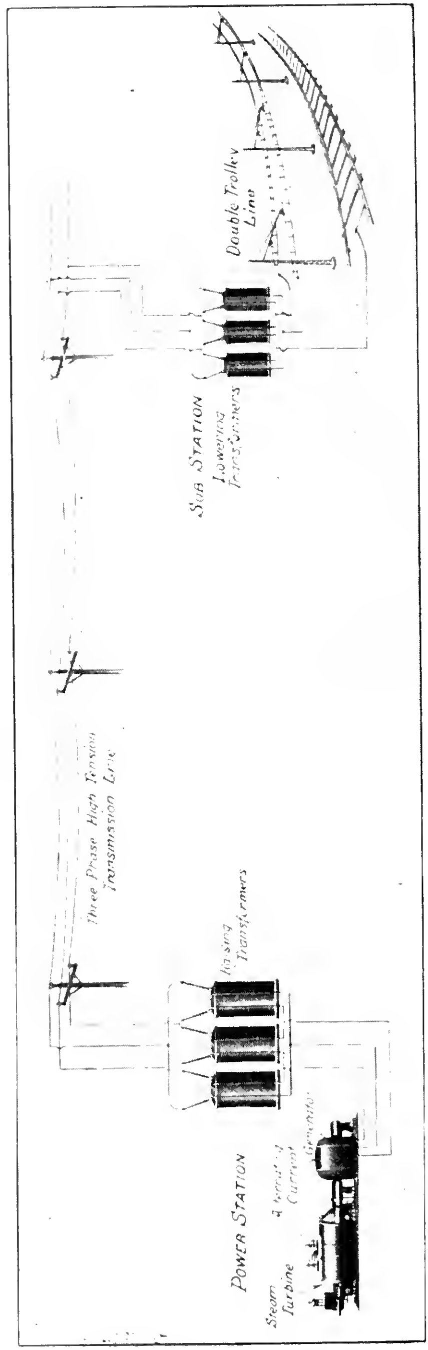


FIG. 16 THREE-PHASE RAILWAY SYSTEM

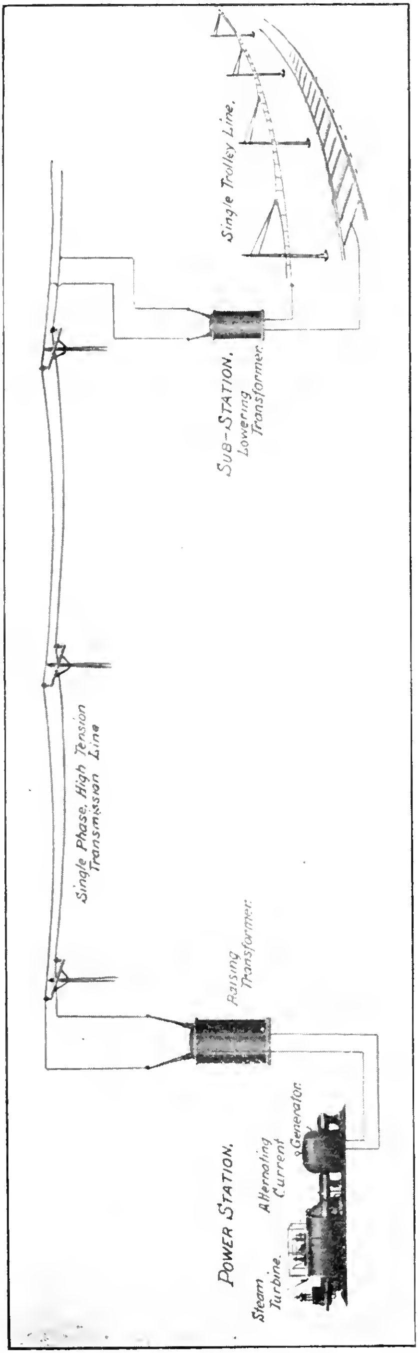


Fig. 17 Single-Phase Railway System

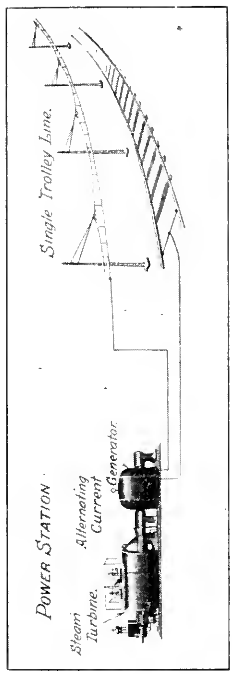


Fig. 18 Single-Phase Railway without Transmission System

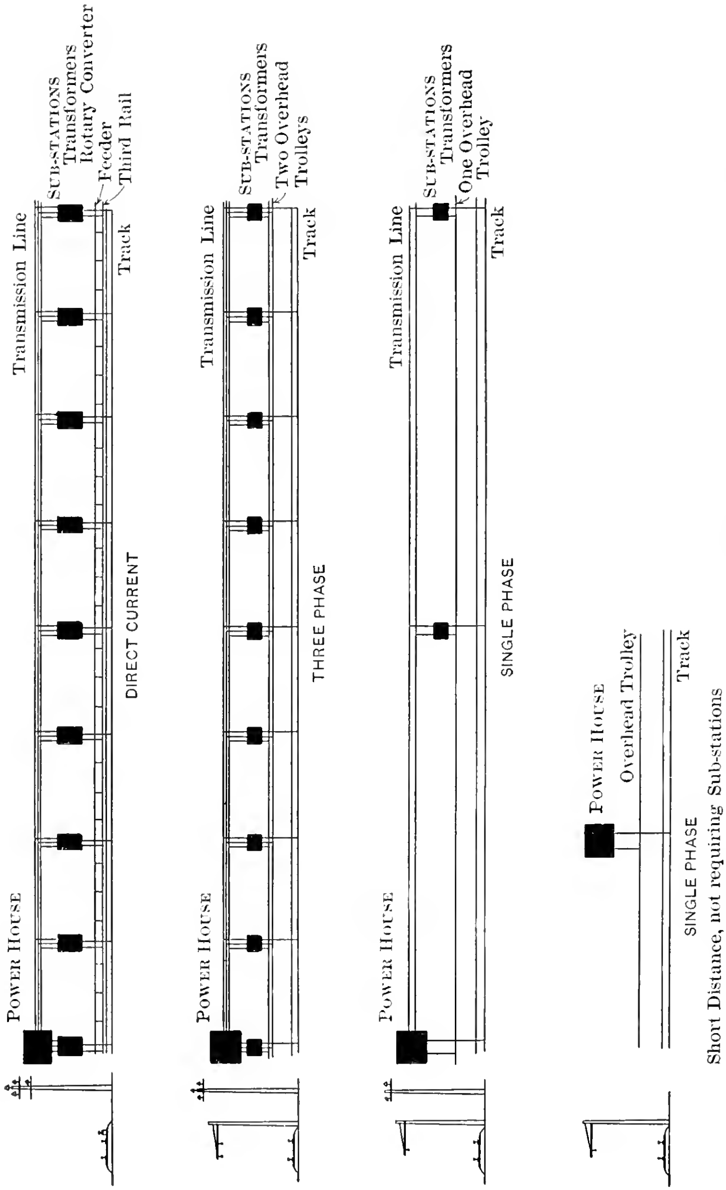


Fig. 19 Electric Railway Systems. Diagrams Showing Transmission Circuits, Sub-Stations and Contact Circuits between Power House and Locomotives Corresponding to Sketches in Figs. 15 to 18

318 The loss between power station and the locomotives is represented by the upper shaded areas. The respective losses in raising transformers, transmission line, lowering transformers, rotary converters and the contact line (comprising trolley or third rail with track return) are segregated.

319 It will be noted that the large losses in the rotary converters appear only in the direct current system. The larger single-phase column shows the losses where the distances are such that it is necessary to use a transmission line and transformers. The smaller single-phase column represents the trolley wires connected to the generators without any intervening transmission line or transformers. The loss of power between power house and locomotives is relatively

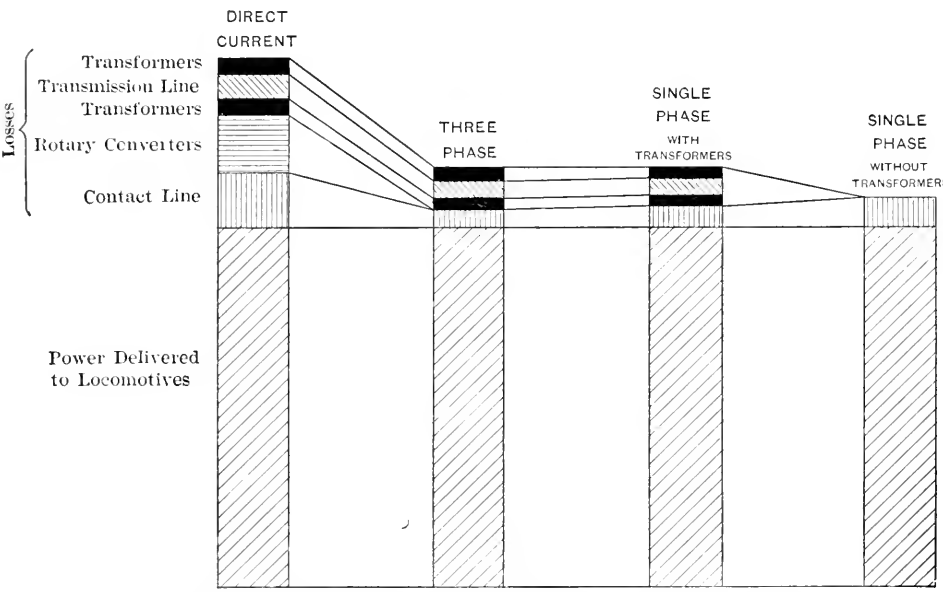


FIG. 20 SHOWING COMPARATIVE LOSSES BETWEEN POWER HOUSE AND LOCOMOTIVES

small as compared with that in any of the other systems. This is the condition on the New York, New Haven & Hartford Railroad, where the power house is distant nearly 20 miles from one end of the line.

COMPARATIVE FIRST COSTS, SHOWN IN FIG. 21

320 Fig. 21 shows the comparative estimates prepared a few months ago of first cost in a particular case for electrification by the direct-current system and by the single-phase system. In the preparation of these estimates the three-phase system was not called for and as no estimate covering it has been prepared, it is not included in the present comparison. The estimates cover a single track line 100 miles long involving both freight and passenger traffic in both through and local service and include twenty locomotives.

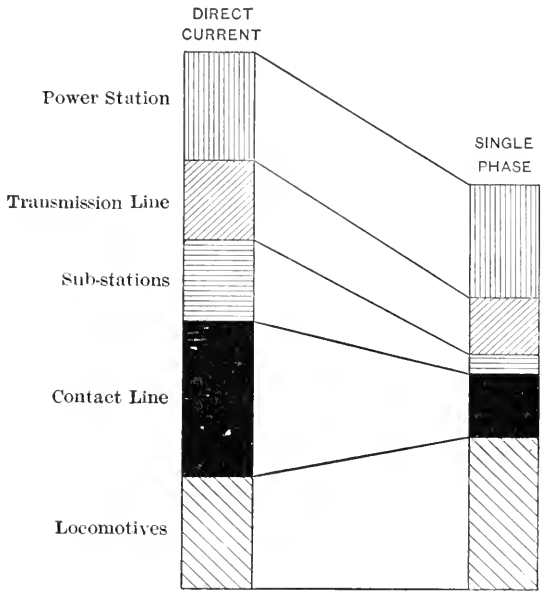


FIG. 21 COMPARATIVE FIRST COSTS FOR DIRECT-CURRENT AND SINGLE-PHASE SYSTEMS IN A PARTICULAR CASE OF 100-MILE SERVICE

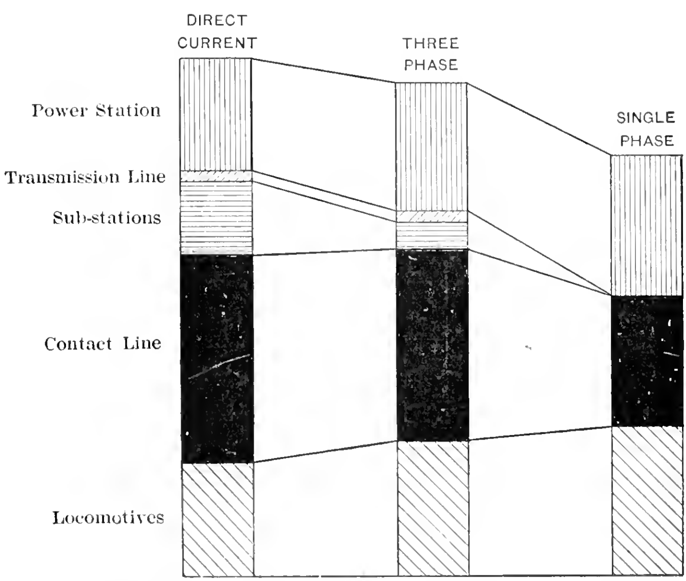


FIG. 22 COMPARATIVE FIRST COSTS IN THE DIFFERENT SYSTEMS FOR A SPECIAL CASE OF PUSHER SERVICE

321 The costs for power station include only the machinery and building and do not include cost of hydraulic development. It will be noted that the considerably less cost of the single-phase system in this case is due largely to the lower cost of contact line and sub-stations.

COMPARATIVE FIRST COSTS, SHOWN IN FIG. 22

322 Fig. 22 shows the comparative estimates of first cost for the three systems for pusher service on mountain grades in a particular case involving the use of twelve locomotives. The total length of line is 32 miles, part of which is single track, part double track and part three tracks. In addition to the main line there is a large yard to be electrified, there being a total of 90 miles of single track. The location of the power station was fixed by non-electrical considerations

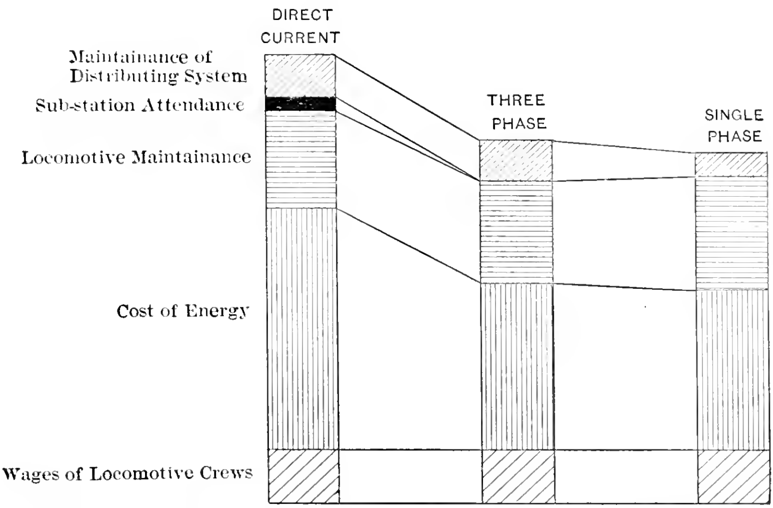


FIG. 23 COMPARATIVE OPERATING COSTS IN THE DIFFERENT SYSTEMS IN A SPECIAL CASE OF PUSHER SERVICE

The distances were such that sub-stations were required when either direct current or three-phase current was assumed, but the entire system could be fed direct from the generators if single-phase current was used.

323 It will be noted that in this case the omission of sub-stations and transmission effects a very considerable saving in favor of single-phase as well as the usual large saving in cost of contact line effected by the use of this system. The cost of the part of the system between the power house and the locomotives in the direct-current system is nearly equal to the cost of both power house and locomotives. On the other hand, the cost of the single-phase contact line, the only intervening element between the power house and the locomotives, is less than one-half of the cost of the direct current transmission and contact system.

COMPARATIVE OPERATING COSTS, SHOWN IN FIG. 23

324 Fig. 23 shows comparative operating costs for the three systems for the pusher service outlined in the preceding diagram of first costs. It should be noted

that these costs do not include fixed charges. If fixed charges were included the difference in operating costs in favor of the single-phase system would be much more marked.

325 In connection with this diagram it should be noted that sub-station attendance is required for the direct current system only. The reason for the three-phase and single-phase systems being so nearly on a par is that this case is an ideal one for the application of the three-phase system since it involves constant-speed operation under constant-load conditions. It is notable, however, that even under these conditions the single-phase system shows somewhat lower operating costs than the three-phase system.

326 The high operating cost with the direct-current system is seen to be due largely to the greater amount of power required for operation by this system on account of the large losses which occur between the power house and the locomotive in this system.

APPENDIX NO. 4

ELECTRIFIED STEAM ROADS AND ELECTRIC ROADS FOR TRUNK LINE SERVICE

The accompanying tables give data upon many of the important railroads on which electricity is used in heavy railway service. Only such data are included as were conveniently available and such omissions or inaccuracies as may occur do not detract materially from the forceful presentation of the extent and character of the use which is now being made of electricity in railway service.

402 The horsepower ratings of the various motor cars and locomotives are in general the nominal ratings for a short period, usually one hour, but as these ratings have been adapted in some cases to the particular service in which the motors are to operate they cannot be taken as a basis for an accurate comparison between the capacities of different equipments.

TABLE 4 SINGLE-PHASE ELECTRIFICATION
ON STEAM RAILWAYS AND IN TRUNK LINE SERVICE

Road	Miles of Line	Miles of Single Track	Line Voltage	Motor Cars		Locomotives	
				No.	h.p.	No.	h.p.
N. Y., N. H. & H. R.R. Main Line	21	100	11,000	4	600	41 2	1400 1600
New Canaan Br.	8	8	11,000	2	500		
Grand Trunk R.R.	3.5	12	3,300	...	...	6	900
Erie R.R. Rochester Div.	34	34	11,000	6	400	...	....
Colorado Southern Ry. Denver & Interurban	46	46	11,000	8	500	...	...
Baltimore & Annapolis Short Line	25	30	6,600	12	400	...	....
Swedish State Ry.	7	7	3,300 20,000	2	240	1	300
Midland Ry., England	8.5	17	6,600	1 2	300 360	...	....
Prussian State Rys.	16.5	31	6,600	20 42 54	250 400 345	1	1500
London, Brighton & South Coast Ry.	8.6	17.2	6,000	16	460	...	....
Rotterdam-Haag-Scheveningen	20.5	46.5	10,000	19	360	...	....
Spokane & Inland	129	129	6,600	28	400	6 5	500 720
Midi Ry. of France	75	...	12,000	30	500	2	1600

TABLE 5 CONTINUOUS-CURRENT ELECTRIFICATION

On Steam Railways and in Trunk Line Service

Road	Miles of Line	Miles of Single Track	Line Voltage	Motor Cars No.	Motor Cars h.p.	Locomotives No.	Locomotives h.p.
New York Cent. R.R.	33	132	650	137	400	47	2200
Pennsylvania R.R.	20	75	650	180	400	24	4000
West Shore R.R.	44	106	650	20	360	...	....
Long Island RR.	42	125	650	137	400	2	1200
West Jersey & Seashore R.R.	75	150	650	68	400	...	...
B. & O. R.R.	3.7	7.4	600	...	..	2.5 5	1600 1100
Northeastern Railway	37	...	600	...	300	2	600
Mersey Tunnel	4.8	...	600	24	400	...	....
Lancashire & Yorkshire Railway	18	60	600	...	600	...	....
Great Western Ry.	5	...	600	...	600	...	....
Metropolitan Railway	...	67	600	56	600	10	800

TABLE 6 CAR EQUIPMENT OF SUBWAY AND ELEVATED SYSTEMS IN AMERICAN CITIES

The Direct-Current Third-Rail System at Approximately 600 Volts is used in all Cases

Road	Miles of Single Track	Motor Cars No.	Motor Cars h.p.
Boston Elevated Railway	19	219	320
Brooklyn Rapid Transit	71	558 101	300 400
Interborough Rapid Transit (New York)	190	969 764	250 400
Hudson & Manhattan (New York)	12	140	320
Chicago & Oak Park	19.4	65	320
Metropolitan West Side (Chicago)	51.1	15 210	400 320
Northwestern Elevated (Chicago)	25.5	20 128	250 320
Southside Elevated (Chicago)	36.5	150 70 150	180 150 110
Philadelphia Rapid Transit	11	100	250

TABLE 7 THREE-PHASE ELECTRIFICATION

On Steam Railways and in Trunk Line Service

Road	Miles of Line	Miles of Single Track	Line Voltage	Motor Cars		Locomotives	
				No.	h.p.	No.	h.p.
Gt. Northern R.R.							
Cascade Tunnel.....	4	6	6600	.	..	4	1900
Italian State Railways.							
Valtelina Railway ..	66	...	3000	10	400	2 7	800 1500
Giovi Railway......	12.4	37.3	3000	..	..	20	2000
Mt. Cenis Tunnel...	4.4	...	3000	..	..	10	2000
Savona Ceva	...	...	3000	..	..	10	2000
Swiss Federal Railways							
Simplon Tunnel.. ..	13.7	14.3	3000	..	..	2 2	1100 1300
Gergal Santa Fé(Spain)	13.1	14.4	5500	..	..	5	320

APPENDIX NO. 5

THE EARLY HISTORY OF SINGLE-PHASE RAILWAY MOTORS

In Par. 22 brief mention was made of two single-phase motors of 10 h.p. built in 1892 by the Westinghouse Company for determining the possibilities of using alternating current for traction work. These motors were designed for 2000 alternations per minute and about 200 volts. They were of the series type, with commutators, and had a relatively large number of poles. They were mounted

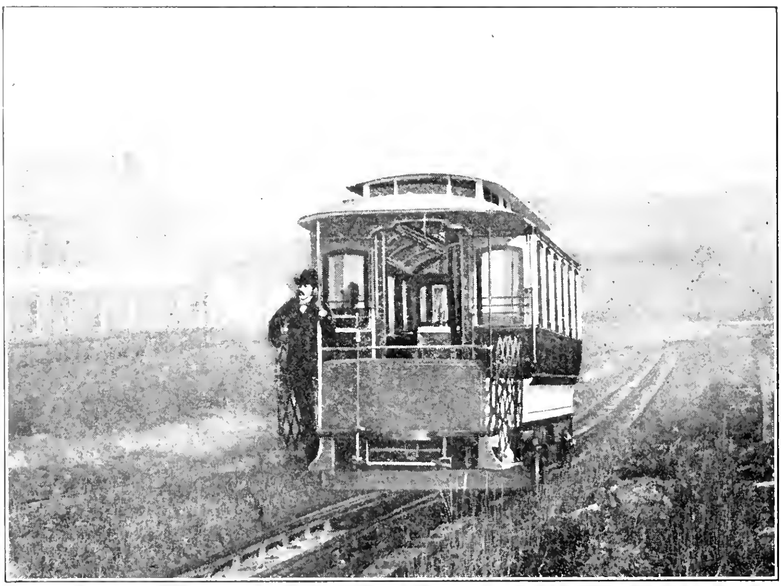


FIG. 24 THE FIRST SINGLE-PHASE ELECTRIC CAR. DESIGNED IN 1892 AND EQUIPPED WITH TWO SINGLE-PHASE SERIES MOTORS

upon a car and tested on a short piece of track with some very short curves and rather steep grades. The car is shown in the accompanying illustration, Fig. 24. The current was supplied from a conductor placed intermediate between the rails. The capacity of the engine and generator used for these tests was insufficient for the service, and the voltage drop in the rails was excessive. The test showed that the motors would run the car, although the current available was hardly

sufficient for operating the car on the curves and grades. A transformer on the car served to transform from a few hundred volts on the supply circuit to that required for the motor. There were several taps on this transformer, and by means of several single-pole switches the voltage could be varied. Several frequencies lower than that for which the motors were designed were employed for testing the motors.

502 Almost the entire effort in railway work at that time was concentrated on electric cars for city service. While the single-phase system gave promise of certain advantages for this service, it was found that there were disadvantages, particularly in the large losses in the conductors for supplying the current, which rendered the single-phase system much less adapted to this service than the direct-current system.

503 It was recognized that the single-phase system would be ideal for locomotive operation, but as there were no such projects then in view, no immediate work was done in building large motors of this type.

504 Some seven or eight years later, the enlarging field of railway operation was showing the imperative need of some practical method by which high tension could be used on the trolley wire in order to minimize the cost of supply circuits. Furthermore, the accrued experience and greater knowledge in the methods of designing alternating-current motors opened the opportunity for the development and perfection of the single-phase system.

505 Motors of 100 h.p. were designed, built and tested on an experimental track. The results of this work and the importance of the single-phase system in railway operation were presented in a paper by Mr. B. G. Lamme before the American Institute of Electrical Engineers in September 1902. This paper awakened widespread interest and was followed by the active development of single-phase apparatus by a number of manufacturing companies, both in America and in Europe. There are now about 60 single-phase railways in operation.

ECONOMICS OF RAILWAY ELECTRIFICATION

By Wm. Bancroft Potter, Schenectady, N. Y.

Member of the Society

National prosperity and importance are largely proportional to facilities for intercommunication, and since overland transportation is to so large an extent dependent on railways any development providing for better railway service is of paramount importance. Steam locomotives and electric motors are the two recognized means of applying power which are available for practical railway requirements. The fundamental principles which underlie the problem of train movement are the same in either instance, but a true comparison of their relative advantages can only be made by a study of each particular method.

2 Much that has been written has treated the subject of electrification of steam railways from the general standpoint of averages, but unfortunately the economic application of electricity is not a subject for generalization—unfortunately, because averages are convenient and usually available, but often lead to erroneous conclusions, either for or against electrification. It is a mistake to assume that the average of the expenses for the entire railroad represents the actual expense for the particular conditions usually existing on the division under consideration.

3 On account of the investment already incurred, and because the question is usually one of determining comparative results, the electrification of an existing steam railway is a more complex problem than the electrical equipment of a new road.

4 Electrification, like any other engineering work, involves an investment against which there will be a fixed charge for interest and a liability of depreciation. The interest is a constant and permanent charge which must be met irrespective of any economy which may be secured by intelligent operation. The subject of depreciation is

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receiving more attention than formerly, the tendency having been to make the operating expenses cover this charge. However classified, the depreciation charge must be accounted for, and it is directly influenced by the character of the equipment with respect to reliability, durability, and capacity to provide for future requirements.

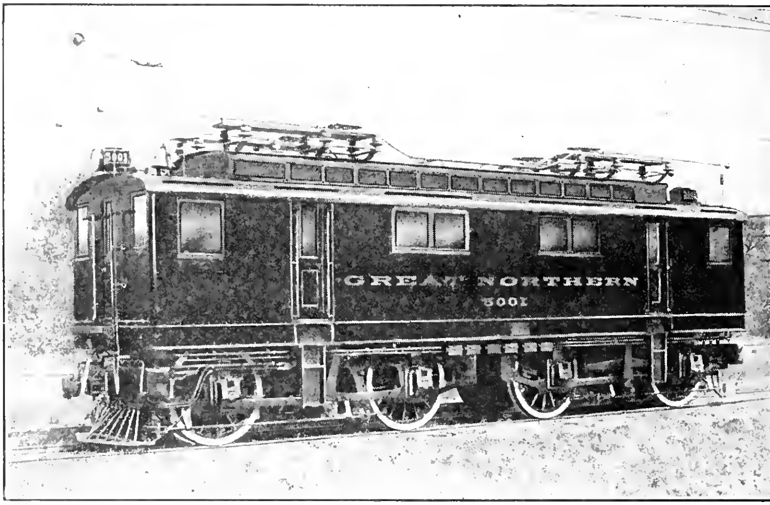

Fig. 1 Three-Phase Locomotive used at the Cascade Tunnel of the Great Northern Railway

Trolley Voltage	6600
Frequency, cycles	25
Total weight, lb.	230,000
Weight on drivers, lb	230,000
Maximum rated draw-bar pull	77,000
Continuous rated draw-bar pull	35,000
Speed, mi. per hr.	15
Duty—Three units to haul 1500-ton train up 2.2 per cent grade	

5 The utilization of higher trolley potentials, made possible with direct current by the development of the commutating-pole motor, and with alternating current by the development of the single-phase motor; the higher speeds of rotary apparatus in the sub-stations; and the development of the steam turbine, have effected a material reduction in the investment required and the cost of operation.

6 The different methods of electrification applicable in any instance should be carefully analyzed with regard to interest, depreciation and operating expense, and only the net result should be

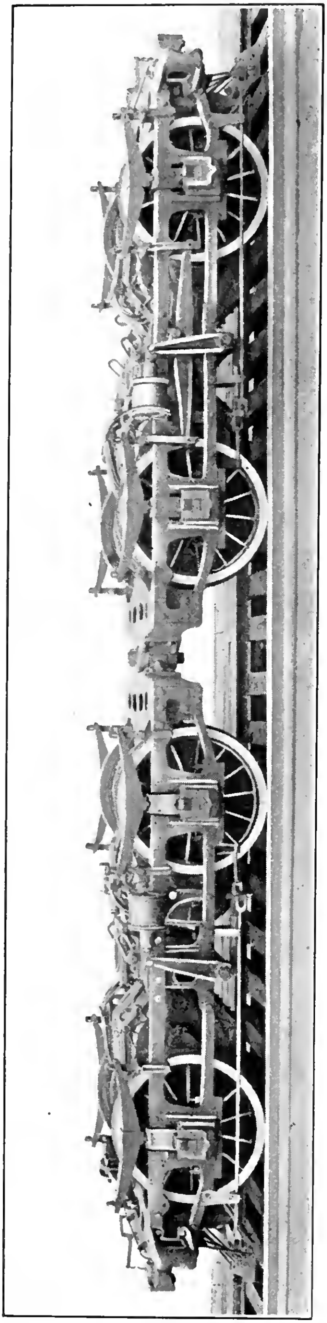

FIG. 2 TRUCKS FOR THREE-PHASE LOCOMOTIVE, GREAT NORTHERN RAILWAY

given consideration in determining the class of equipment. In this connection it is well to bear in mind that the expenditure is a lump sum which can be accurately determined, while depreciation and operating expense can only be approximated. Reference to the corresponding items of expense on railways operating under conditions comparable to those of the line to be electrified, will supply the most reliable figures. Future traffic developments must not be overlooked and the type of initial electrification should be selected with due regard to the ultimate requirements.

7 There would undoubtedly be an advantage in having the character of the energy supplied to the contact conductor uniform, but this is out of the question on account of the great difference in the requirements of specific conditions, such as congested urban or suburban service and comparatively infrequent trunk line train movements.

8 The sub-station and rolling stock may be equipped for operation with direct current or alternating current, single-phase or three-phase, and what is commonly spoken of as "the system" usually refers only to that part of the general scheme of electrification which comprises the sub-station and rolling stock equipment. There are exceptional

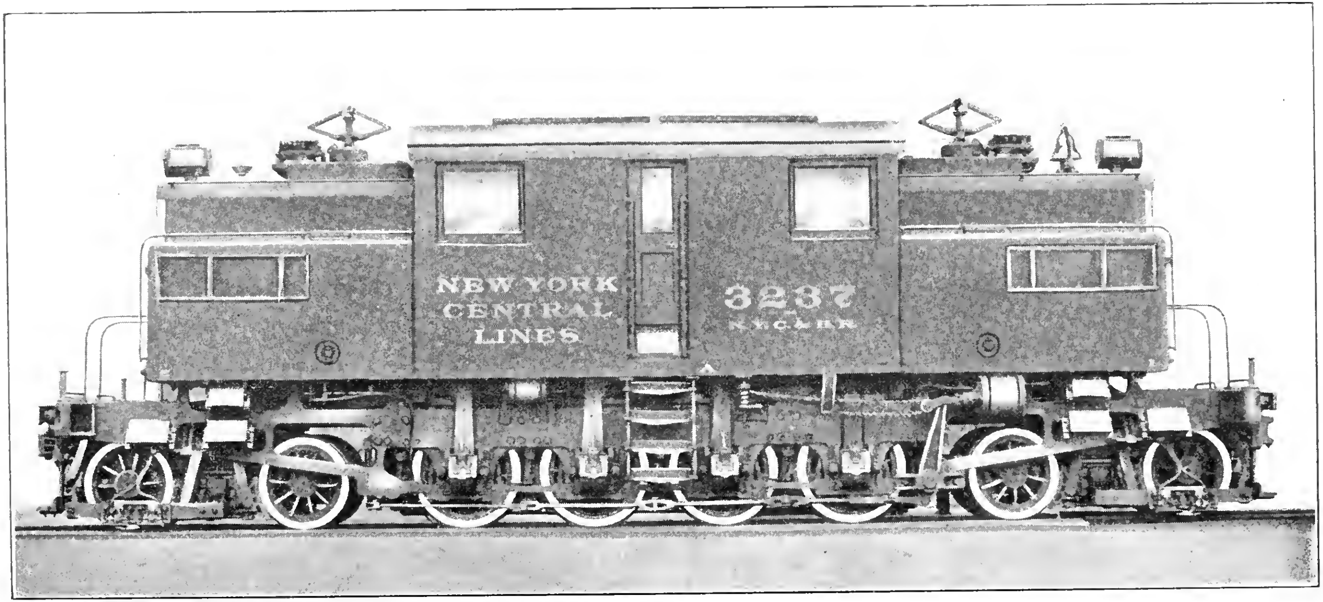

FIG. 3 DIRECT-CURRENT LOCOMOTIVE USED IN THE NEW YORK CENTRAL ELECTRIFICATION AT NEW YORK

Voltage	660, D. C.
Total weight	230,000
Weight on drivers, lb	141,000
Maximum rated draw bar pull, lb.	47,000
Continuous rated tractive effort, lb	7,250
Speed, mi. per hr	60

cases where the power station and transmission lines have direct relation to the rolling stock equipments; but with the development of alternating-current transmission, this is less frequently the case than it was a number of years ago when 600-volt power stations supplied power directly for the operation of 600-volt motors.

9 The development of apparatus for higher voltage direct current has so far increased its scope that direct current at either 600 voltage or higher may be considered the most economical for city and interurban service, and for the electrification of steam railways where the density of traffic is sufficient to require a relatively large

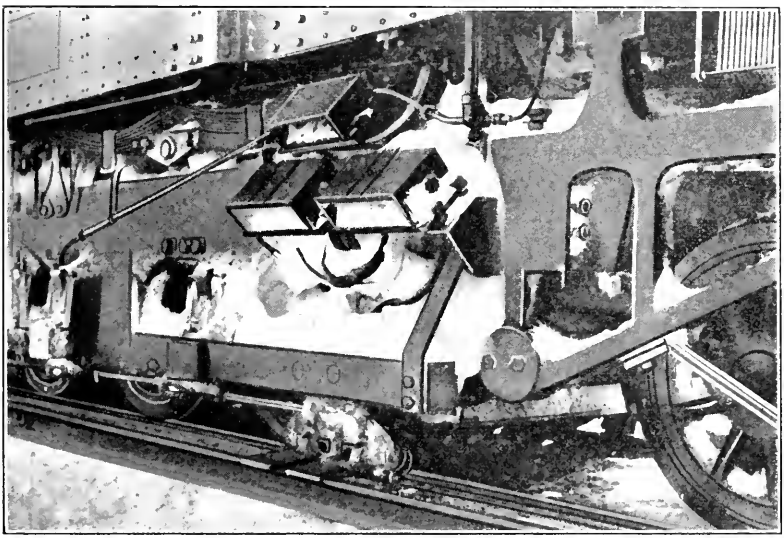

Fig. 4 Portion of a New York Central Locomotive after Running through Snow

investment for rolling stock, as compared with that required for the secondary distribution system and the sub-station apparatus.

10 Single-phase and three-phase rolling stock equipments are applicable only to exceptional conditions. The reason for this is the greater first cost of such equipments. This is especially true when comparing single-phase with direct-current. The type of equipment used on the rolling stock may well be a more important factor in the economy of investment and operation than the scheme of power distribution.

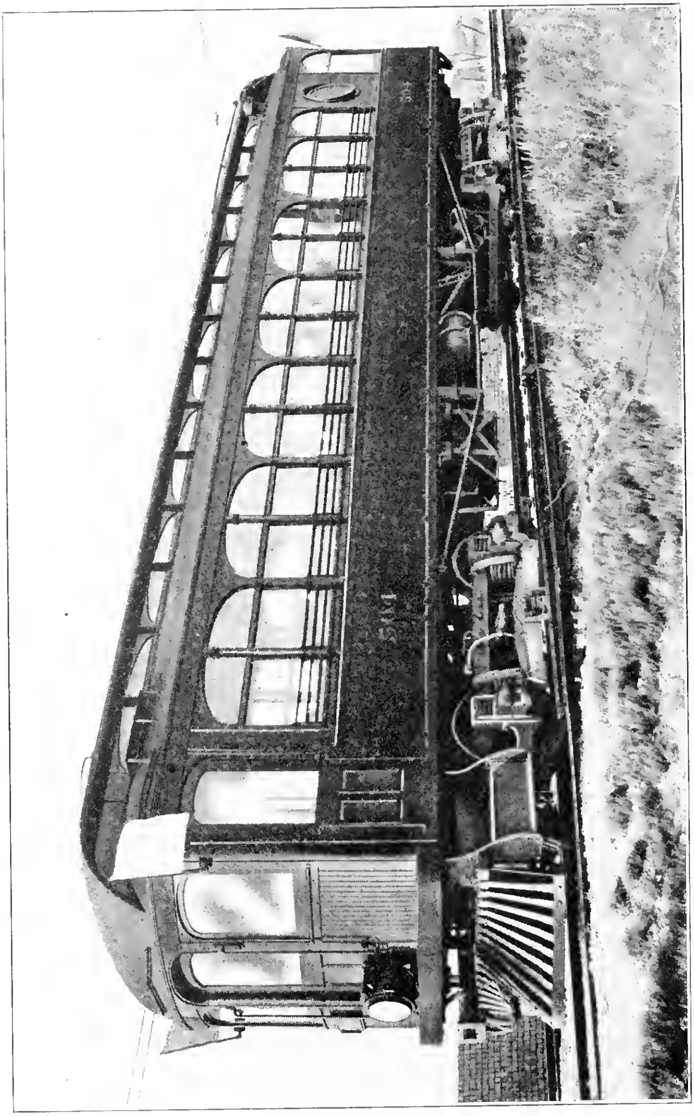

Fig. 5 Typical American Interurban Car, West Shore Railroad

11 Under the conditions which exist in America, direct-current and single-phase are applicable to either level or grade work; while three-phase will probably be limited to the latter where its regenerative feature of returning energy to the line may be of value. The relative economy of the different systems of electrification is dependent on the density of traffic and the character of power available, rather than on the length of the railway.

12 In cases where purchased power is used, or is depended on as a reserve, the frequency of the current supplied by the power company will have a bearing on the cost of sub-stations, and will thus affect the choice of the system. For direct-current operation,

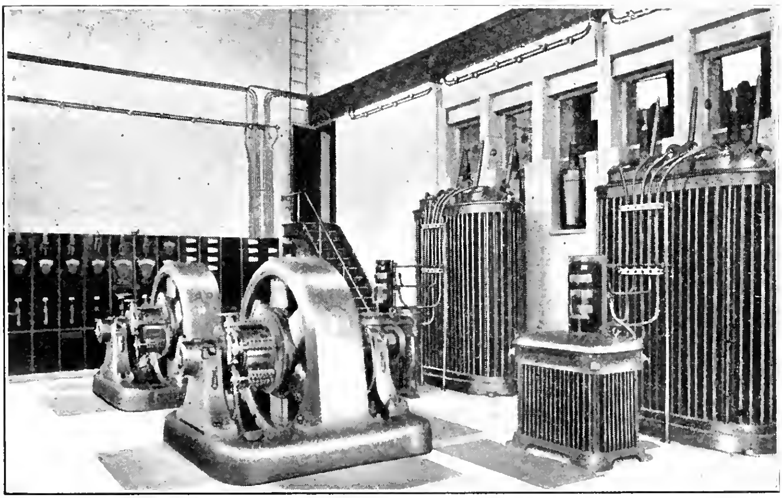

FIG. 6 INTERIOR OF 60,000-VOLT INTERURBAN SUB-STATION, CLARKS MILLS, N. Y.

rotary apparatus is used for converting the alternating into direct current, and the frequency of the supply is therefore relatively unimportant. For single-phase operation under the usual conditions, a frequency of not more than 15 cycles is desirable; and to provide this frequency, rotary frequency-changers are as necessary as are rotary converters in the case of direct current, since the frequency of existing power companies ranges from 25 to 60 cycles.

13 With power supplied at the proper frequency for single-phase operation, permitting the use of static transformers and dispensing with frequency changers, the amount of energy required for a given

trunk line service is in many cases nearly the same as for direct current, the greater weight of the equipped rolling stock, and the lower efficiency of the single-phase equipments, offsetting the rotary converters and trolley-line or third-rail losses of the direct current.

TABLE 1 REASONABLE VALUES FOR TRUNK LINE SERVICE

SUB-STATIONS

	600 v. D. C.	1200 v. D. C.	11,000 v. 1-Phase	11,000 v. 3-Phase
First cost per kw., complete	$26	$28	$11	$12
Comparison of installed kw., %	200–250	100–125	100	100–125
Load factor, machines in service, %	20–40	35–70	40–80	30–60
Average efficiency, %	78–88	87–92	97–98	97–98
Yearly operation and maintenance, each station	$5000	$5000	$2500	$2500

CONTACT CONDUCTORS[1]

	Third Rail		Overhead	
First cost, per mile	$5000 to $7000	$5500 to $7500	$3500 to $7000	$4500 to $8000
Efficiency, %	88–92	90–96	93–97	93–97
Maintenance per mile per year	$75–$125	$100–$150	$100–$200	$125–$250

ROLLING STOCK[2]

	600 v. D. C.	1200 v. D. C.	11,000 v. 1-Phase	11,000 v. 3-Phase
LOCOMOTIVES				
First cost, each	$44,000	$47,500	$64,000	$58,000
Weight, tons (2000 lb.)	125	125	160	160
Average efficiency, locomotive wheels to trolley, %	85	85	79	81
Maintenance per locomotive per mile, cents	4	4	8	5
MOTOR CARS (COMPLETE)				
First cost, each	$12,000	$13,500	$20,000	....
Weight, tons (2000 lb.)	43	44	54	....
Average efficiency, wheels to trolley	82	81	73	....
Maintenance per car mile, cents	2	2.2	3.5	....

[1] Variation in cost of third rail due to different weights of rail which may be required. Variation in cost of overhead due to variation in the class of construction, such as with wooden poles or with steel bridges.

[2] Other weights of locomotives will cost more or less about in proportion to their weights. With gearless direct-current locomotives, the average efficiency of locomotive wheels to trolley is approximately 88 per cent.

CONDITIONS DETERMINING RAILWAY EQUIPMENT

14 The principal conditions which determine railway equipment are:

DATA SHEET

a Profile of road.
b Transportation required, *i.e.*, weight of trains or seating capacity of cars.
c Frequency of trains.
d Length of individual runs or distance between stops.
e Schedule required.
f Length of railway to be electrified.

15 In the selection of the electrical system best adapted to a particular set of conditions there are three items to be considered: (*a*) sub-stations, (*b*) contact conductors, (*c*) rolling stock. A comparison of these items determines the relative economic values of the systems. There are certain features under each of these items which may properly be examined. For trunk line service the values in Table 1 will be found within reasonable limits for the usual requirements.

16 We will consider briefly the effect of changes in the Data Sheet items (Par. 14):

a Profile: From a level country to a limiting grade of 1 or $1\frac{1}{2}$ per cent there will be little difference in the relative values of the systems. With steeper grades the conditions will be more favorable for alternating current.

b Traffic Requirements: Heavy individual train units favor the alternating-current system with exception of the locomotives; light trains or multiple-unit operation favor the direct-current system.

c Frequency of Trains: Infrequent service with a relatively small number of locomotives favors the alternating-current, frequent service the direct-current. With increase in number of trains, the direct-current systems gain relatively faster than the alternating-current in economy of operation, due to relatively decreased sub-station operation, increased sub-station efficiency, and lower cost of equipment maintenance. It is therefore well to consider what the ultimate traffic density may be and select the system best suited to meet these requirements.

d, e *Distance between Stops and Schedule Required:* Variations in these will not affect the relative value of systems unless extreme requirements, such as high schedule speed with short runs, make the use of direct current imperative.

f *Length of Road:* For a similar character of service throughout, the railroad may be of any length without affecting the relative desirability of the various systems. What is suitable for the first fifty miles will be equally suitable for any extension.

An examination of these variables will show that a change in the conditions to be met will radically change the relative economic value of the systems of electrification.

17 The single-phase system, by reason of the apparent simplicity of its elements and the utilization of higher potential for the contact conductor than is possible with direct current, is admittedly very attractive. There is the other side of the question, that it is impossible to build a single-phase commutating motor comparable in first cost and maintenance with a direct-current motor. Over this subject of alternating-current single-phase vs. direct-current systems there has been a great deal of controversy. It is our opinion that comparative results obtained up to the present time are in favor of direct-current.

18 Desirable as would be a standard system for all classes of service, we cannot hope to establish such a standard should it impose an additional expense without adequate return. A summing up of all the elements of each electrical system will generally lead to a definite showing of which system is most desirable to meet specific conditions. For trunk line service a higher potential than 600 volts will unquestionably be used; 1200 volts direct-current will prove economical in some cases, but a still higher voltage is required to provide economically for the heavier intermittent service. Whether this potential will be 1800 or 2400 volts direct-current or 11,000 volts alternating-current cannot be settled arbitrarily.

INTERURBAN RAILWAYS

19 Let us consider the interurban railway situation in the United States, particularly in regard to the various available schemes of electrification. These are, 600-volt direct-current, 1200-volt direct-

current, and single-phase, the three-phase being debarred on account of the complications of the necessary double overhead-distribution system.

20 The application of single-phase to new projects has been practically abandoned, there having been but one or two new installa-

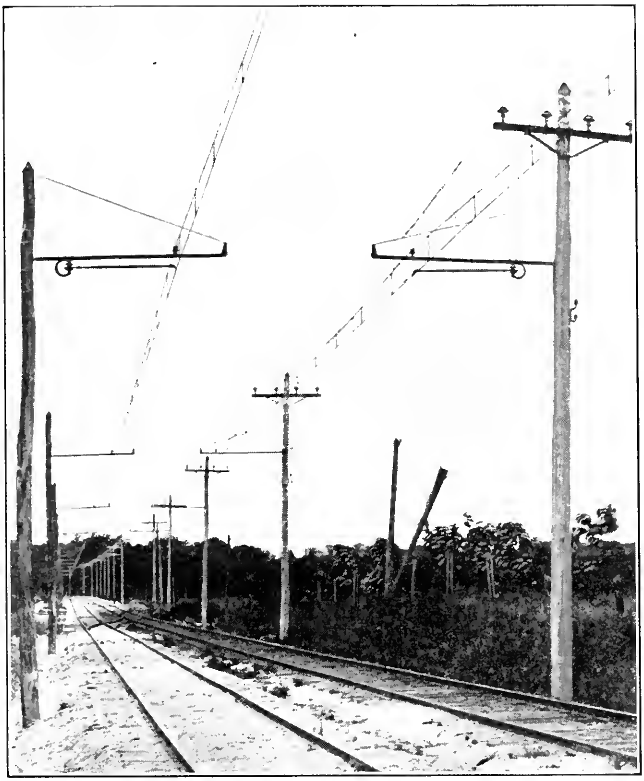

FIG. 7 TYPICAL AMERICAN OVERHEAD 6600-VOLT SINGLE-PHASE INTERURBAN TROLLEY LINE, BALTIMORE & ANNAPOLIS SHORT LINE, ANNAPOLIS, MD.

tions in the last three years. This arrested development of a system which for a short time held forth considerable promise, has been brought about by a general recognition of its limitations. Experience has shown these to be:

a Excessive weight of rolling stock.
b Excessive cost of rolling stock.

c High cost of equipment maintenance.
d Increased power consumption.
e Rapid depreciation of motor.
f Rapid depreciation of car bodies and trucks.
g Increased cost of maintaining track and road-way.

Moreover it is recognized that any interurban road in the United States must be capable of operating over existing city tracks from 600-volt direct-current trolley, a condition which hampers the single-phase system on account of increased complications in the control system.

21 For interurban railways a potential of 1200-volt direct-current has been selected, because with the motors wound for 600 volts the car may be operated at the same speed from either 600 or 1200-volt trolley, by connecting the motors all in parallel for 600-volt operation, and two in series with two groups in parallel on a 1200-volt section.

22 To show clearly the relative merits of the systems we have made an analysis of an interurban railroad 100 miles long with cars in each direction every hour. This condition represents practically the minimum car requirements in the United States, and is therefore favorable to the single-phase. It is obvious that any increase in traffic density will be relatively more favorable to the direct-current system on account of the lower first cost of cars, lower car maintenance and relatively lower cost of sub-station operation.

23 Assume a typical interurban condition:

a Profile: rolling country.
b Transportation required: passenger cars to seat 50 passengers and having baggage compartment, or the equivalent of 60 passengers without baggage compartment.
c Frequency of trains: one every hour in each direction.
d Average distance between stops: 3 miles.
e Schedule speed: 33 miles per hour.
f Length of road: 100 miles.
g To operate on existing 600-volt city tracks.

The general data required are approximated in Tables 2 to 7.

24 There will be an additional cost of operation and maintenance with the single-phase system for the items of track and roadway, due to additional weight of cars, car shop expenses in providing greater facilities for shop inspection and repairs, and greater skill in superintendence of equipment. In a number of instances this

has been found to amount to several cents per car mile. A conservative estimate would require at least one cent per car mile to be added for these items.

25 The comparison in Table 7 brings out the fact that even for conditions selected as favorable to the single-phase system, the 600-

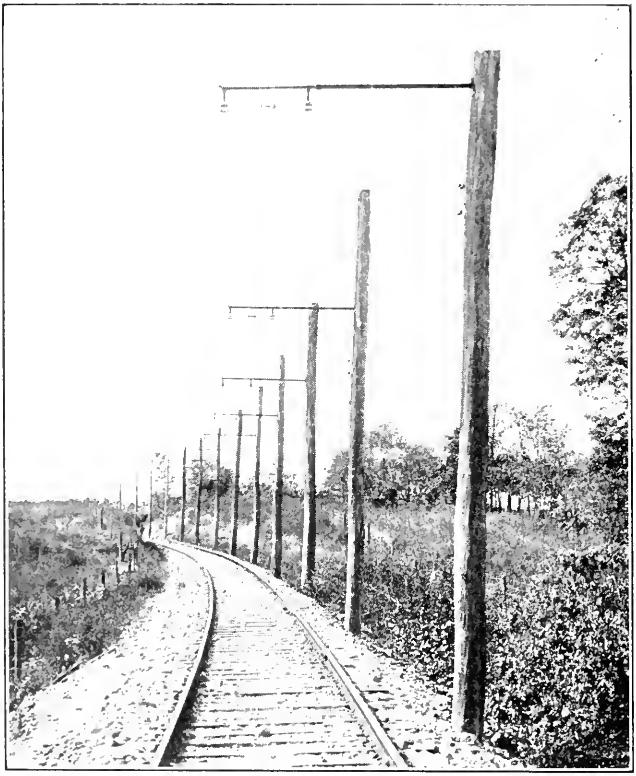

FIG. 8 1200-VOLT DIRECT-CURRENT OVERHEAD-LINE CONSTRUCTION OF THE PITTSBURG, HARMONY, BUTLER & NEW CASTLE RAILWAY, PITTSBURG, PA.

volt direct-current system is the more economical considering operation, maintenance and fixed charges. An examination of the elements which enter into the first cost and operation of a system will show at once that as the density of traffic increases there is a rapid gain in the relative advantage of the direct-current over the single-phase system.

TABLES RELATING TO TYPICAL INTERURBAN ELECTRIC SERVICE

TABLE 2 GENERAL DATA FOR CARS

	600 v. D. C.	1200 v. D. C.	6600 v. A. C.
Number of cars	15	15	18
Seating capacity, passengers	60	60	60
Distance between stops, miles	3	3	3
Schedule speed, miles per hour	33	33	33
Maximum speed, miles per hour	48	48	55
Weight each car, tons (2000 lb.)	35	36	43
Car miles per day	3000	3000	3000
Miles per car in service per day	300	300	300
Miles per car per day, average[1]	200	200	166
Estimated maintenance per car mile, cents			
a Electrical	0.70	0.77	1.50
b Mechanical	1.00	1.00	1.25
Total car barn expense	1.70	1.77	2.75
Amperes starting car	520	280	75
Amperes running car	174	94	24
Kilowatt hours per car mile at car	2.8	2.88	3.78
Cost each car complete	$10,000	$11,500	$17,000

TABLE 3 SUB-STATIONS

	600 v. D. C.	1200 v. D. C.	6600 v. A. C.
Number of sub-stations	9	4	2
Estimated momentary demand			
Cars starting	1	1	2
Cars running	1	1	0
Peak load, kilowatts	416	448	670
Average load, each sub-station, kilowatts	52	120	275
Size each unit, kilowatts	300	300	300
Number of units	2	2	3
Load factor (machines in service)	0.17	0.40	0.46
Average efficiency	0.76	0.87	0.96
Cost each sub-station complete	$24,000	$26,400	$10,000

[1] On twelve American single-phase interurban roads the average miles per day called for on the published time tables, divided by the number of cars owned, is 138; on four 1200-volt roads which have been operating over a year this number is 237, the larger number of alternating-current cars being required on account of the fact that a greater number are necessarily held in the barn for inspection and maintenance purposes. This explains why in the table above 18 alternating-current cars are assumed and 15 direct-current cars.

TABLE 4 FEEDER COPPER REQUIREMENTS

	600 v. D. C.	1200 v. D. C.	6600 v. A. C.
Maximum momentary demand midway between sub-stations.			
Cars starting	1	1	2
Cars running	0	1	0
Amperes	520	374	150
Distance between sub-stations	11.8	28	66.6
Equivalent stub-end feed	2.9	7	16.6
Feeder required additional to 4/0 trolley	4/0	1/0	none
Cost overhead construction per mile, including both trolley and feeder	$2300	$2100	$1900

Bonding taken as $400 per mile of track.

Transmission line taken in each case as $840 per mile of track and assumed to run entire length of right of way.

Power house: No power house is included, but it is assumed that power is purchased at the power station bus at one cent per kw.-hr. and fed at any convenient point into the transmission line.

TABLE 5 POWER CONSUMPTION

	600 v. D. C.	1200 v. D. C.	6600 v. A.C.
Total kilowatt-hours per day at cars	8400	8650	11,400
Efficiency, secondary distribution	0.90	0.90	0.94
Sub-stations	0.76	0.87	0.96
Transmission line and power house step-up transformers	0.94	0.94	0.94
Combined efficiency	0.64	0.74	0.85
Kilowatt-hours per day at power house	13,100	11,700	13,400

TABLE 6 SUMMARY OF COSTS

First Costs

	600 v. D. C.	1200 v. D. C.	6600 v. A. C.
Transmission	$ 84,000	$ 84,000	$ 84,000
Sub-stations	216,000	106,000	20,000
Secondary distribution	230,000	210,000	190,000
Bonding	40,000	40,000	40,000
Cars	150,000	172,500	360,000
Total	$720,000	$612,500	$694,000

Annual Fixed Charges

Depreciation	Life Years	Annuity 5%	600 v. D. C	1200 v. D. C.	6600 v. A. C.
Transmission	20	30 34	$ 2,500	$ 2,500	$ 2,500
Sub-stations	20	30 34	6,500	3,200	600
Secondary distribution	15	46 34	10,600	9,700	8,800
Bonding	10	79.50	3,200	3,200	3,200
Cars (A. C.)	12	62 83	......	......	22,600
Cars (D. C.)	15	46.34	6,900	8,000	......
Total Depreciation		.....	$29,700	$26,600	$37,700
Interest and Taxes					
Interest 5%, taxes 1.5% of cost of electrical material			$46,000	$39,800	$45,000
Insurance					
1.5% of sub-station and car costs			$ 5,500	$ 4,200	$ 5,700
Total fixed charges			$81,200	$70,600	$88,400

Annual Operation and Maintenance

	600 v. D. C.	1200 v. D. C.	6600 v. A. C.
Transmission	$ 3,500	$ 3,500	$ 3,500
Sub-stations	17,000	7,600	500
Secondary distribution, including bonds	9,000	9,000	10,000
Cars	18,500	19,500	30,100
Power at one cent per kw.-hr	47,800	42,700	49,000
Additional cost maintenance of track and roadway, shops and supervision, due to heavier cars and more expert supervision required for the single-phase	......	......	10,900
Total	$95,800	$82,300	$104,000

TABLE 7 COMPARISON OF COST OF SYSTEMS

	600 v D. C.	1200 v. D. C.	6600 v. A. C.
1 First cost	$710,000	$612,500	$694,000
2 Fixed charges	$ 81,200	$ 70,600	$ 88,400
3 Operation and maintenance	95,800	82,300	104,000
4 Annual cost (Item 2 plus Item 3)	$176,000	$152,900	$192,400
Based on 1,095,000 car miles per year, additional annual charge per car mile above the cost for 1200 volts, in cents	2 1	0	3 6

CONCLUSION

26 The saving effected by the 1200-volt direct-current system is so marked that a great increase in the adoption of this potential for this class of interurban railroading may be anticipated, and on the other hand it will not be surprising if the single-phase interurban system is entirely discarded in America, unless some marked improvement is made in the art and a more economical equipment made available. There is no question regarding the mere movement of trains by any particular system—this may be taken for granted. The study of electrification is really a problem in economic engineering and not simply a technical problem.

27 Reliability of operation is of the greatest importance, not only to the public but to the operating company, and in this respect the electric motor with its simpler construction, even though the general service is supplied from a central power station, has proved its superiority over the steam locomotive. Except in the case of some extraordinary accident, the power station, sub-stations and transmission line, in their entirety, are rarely rendered inoperative. The liability to interruption is principally centered in the equipment of the rolling stock, and for this reason the mechanical and electrical design of the motors, control and equipment devices, should receive careful consideration.

28 The electrical equipment of motor cars and locomotive is exposed to a large extent to dirt, water and snow, and not being particularly convenient for inspection, it usually receives less attention than the apparatus in the power station and sub-stations. It is the custom on many roads to give the equipments a regular inspection once in a thousand or fifteen hundred miles, depending on experience, and to dismantle them for a thorough overhauling once a year. The character of the rolling stock equipment is a factor of far more importance to the reliability of the service than is often appreciated.

29 The steam locomotive has been brought to its present state of development through many years of experience. It is an exponent of the highest type of mechanical design, and notwithstanding its limitations, is remarkably efficient as a source of power. During the past twenty years the power of the steam locomotive has been practically doubled, but the demand today is for still greater power.

30 The multiple-unit idea, to which electric service is so well adapted, was utilized in the design of the Mallet type of steam locomotive where the driving engines of two practically separate

locomotives are supplied with steam from a single boiler. Mallet locomotives have been built having a weight of 441,000 lb. on the drivers, the boiler having over 5800 sq. ft. of heating surface and a grate area of 100 sq. ft. To fire properly a locomotive of this capacity is difficult, and unlike the electric locomotive, its effectiveness depends on the steam from its own particular boiler.

31 With existing road clearances the steam locomotive unit, controlled by a single engineer, seems to have reached nearly the limit of power. The power of a steam locomotive being limited by the capacity of its boiler, an increase in speed can be secured only by a proportional reduction in tractive force. The electric locomotive, on the other hand, is supplied with practically unlimited power from an independent power station, and can maintain a speed and tractive force that would be impracticable with a steam locomotive. The application of electric locomotives to passenger and freight service will result in faster schedules with equal or even heavier trains than are at present handled by steam locomotives.

32 Since the electric locomotive is equipped with a number of independent motor units, controlled by one engineer from a single master controller, it makes no difference, considering the complete locomotive as a machine, whether it be built as a single unit, or as two or three units having the same total weight on the drivers. For convenience in operation and repairs, it is probable that a single electric locomotive unit will be limited to a weight between 200,000 and 300,000 lb. on the drivers, even when built for the heaviest service. There are electric locomotives now under consideration which as single units will exert a maximum tractive effort of 90,000 lb., and which will be capable of maintaining a tractive effort of 35,000 lb. at a speed of 30 miles per hour.

33 Many of the terminal and tunnel electrifications have been brought about from the desire to do away with the danger and nuisance caused by smoke and gas. The elimination of smoke has also an economic aspect in the electrification of terminal stations, in permitting material improvement in the character and value of railway buildings. The Quai d'Orsay terminal of the Paris-Orleans Railway in Paris, which has been in operation since May 1900, was the first instance where a steam railway profited by this feature of electrification.

34 The enhanced value of railway buildings is seen to a marked degree when terminals are electrified in large cities in which land values are high. The fact that electric operation will permit platforms

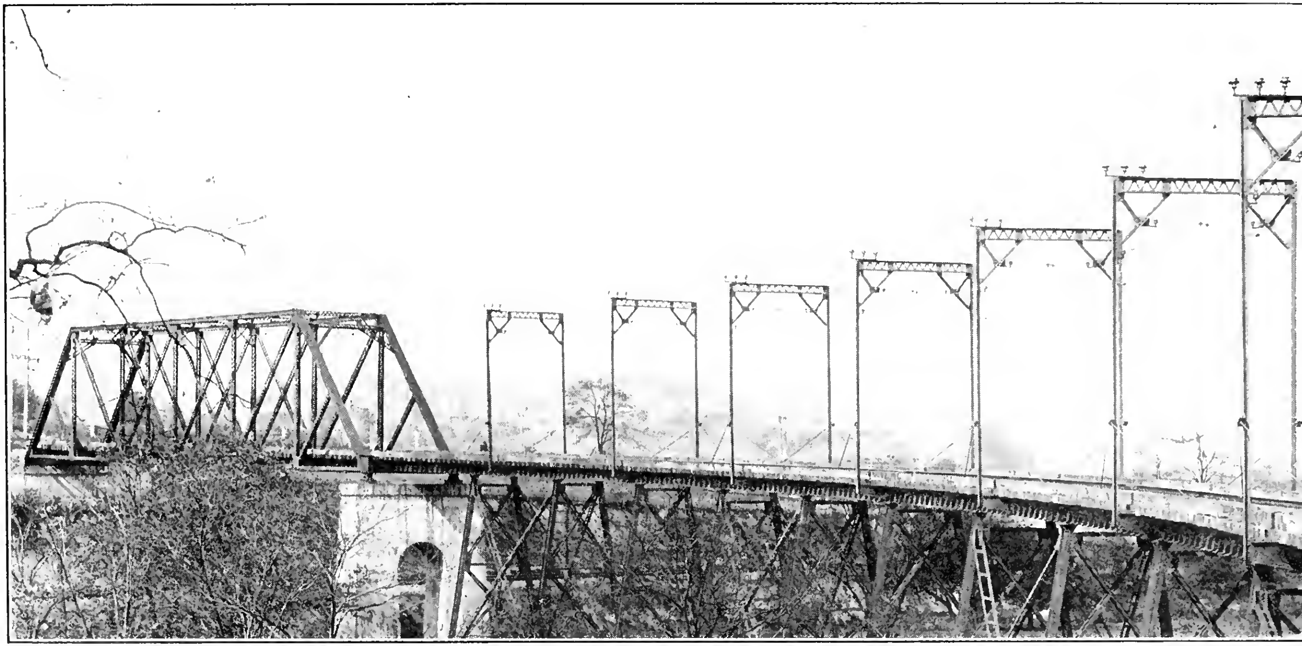

Fig. 9 1200-Volt Overhead Line Construction on Steel Trestle, Pittsburg, Harmony, Butler & New Castle Railway, Pittsburg, Pa.

on two or more levels adds greatly to the capacity of the station, or conversely, decreases the land area required for given traffic facilities. In the case of the New York Central terminal in New York City, there will be two levels of platforms, the entire suburban facilities being placed below those of the main line. The Pennsylvania terminal in New York is another instance of station design affording facilities for handling traffic that would be impossible under steam operation.

35 The electric locomotive is well adapted for the handling of trains where the character of the service will not permit the operation of individually equipped cars. Where the service is self-contained, individually equipped motor cars, operated in trains with multiple-unit control, are recognized as providing for the most efficient handling of traffic.

36 Economy in operation will be secured by proportioning the number of cars in a train to the traffic required during different hours of the day. The patronage on which the gross receipts depend will be much encouraged by providing a service with short intervals between trains. In the study of any scheme of transportation, due regard should be given not only to economical operation but also to the method of handling which will insure the maximum gross receipts.

37 The author desires to express his thanks to Mr. C. E. Eveleth for his assistance in the preparation of this paper.

HANDLING LOCOMOTIVES AT TERMINALS

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INTRODUCTION

Detail methods in the handling of locomotive terminals vary so widely that the scope of this paper has been limited to well established practices along certain definite lines, in the United States and Canada, with some personal suggestions. Steam locomotive terminals alone are sufficiently developed to permit of extended discussion.

2 Terminals differ very much in importance and the paper will be confined largely to the more important ones, leaving it to the judgment of the reader to decide what parts apply to the smaller terminals. By the designation "important terminals" is meant those caring for about 100 locomotives during each 24 hours.

LOCATION OF TERMINALS

3 Starting with a terminal at each end of a railroad the intermediate terminals are located as the topography of the line, the location of important towns, or other factors, may indicate. Some years ago the distance between locomotive terminals was shorter than is considered desirable now, and generally the divisions have been lengthened so that at the present time they range in length from 100 miles to 200 miles; divisions approximately 150 miles in length are quite common. Frequently there are locomotive terminals between the division extremes, but these are usually for local and suburban runs and are of lesser importance, although a few years ago they were the important terminals.

4 From the standpoint of operation, the engine house and its accessories at the divisional point should be located close to the freight

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yard, for freight locomotives, and to the passenger station, for passenger locomotives. This condition is more readily fulfilled for freight than for passenger service. For the latter it is sometimes necessary to place the engine house five to ten miles from the passenger station where the locomotive is detached from the train. This requires the introduction of separate crews for handling the locomotives between the engine house and the station and also necessitates exceptional methods of inspection and reporting and calling the crews and equipping the locomotives for the next trip. Such conditions exist at Buffalo on the New York Central & Hudson River R. R. On the other hand the station is not a terminal of the road the through trains may be if stopped near the engine house and the locomotive detached and attached there; such is the method on the Lake Shore & Michigan Southern Railway at Cleveland.

APPROACH TO THE TERMINAL

5 The route between the train terminal and the engine house should be as direct as possible and independent of all other movements. This is not always possible, however, and in passenger service more particularly, the route is largely made up of main line track. Especially is this true when the locomotive terminal is at some distance from the station.

LINE OF SEPARATION OF RESPONSIBILITY

6 So far as concerns the mechanical operation of the locomotives, the mechanical department must be responsible. There are two well recognized and quite different forms of railroad organization: the departmental, in which the mechanical department has supervision over the design, maintenance and mechanical operation of the locomotives; and the divisional, in which the mechanical department has supervision over the design, construction and general condition of the locomotives, and the transportation department has supervision over running, maintenance and mechanical operation. In either of these organizations the responsibility for the locomotives must change, so far as individual officials are concerned, at some place adjacent to the engine house. In some organizations this change is made at the turntable, or its equivalent, there are a very limited number of rectangular engine houses, notably at the St. Louis passenger terminal, where a transfer table is used and a turntable is not necessary. In these

organizations the official in charge of the engine house, who is a part of the mechanical department, has supervision over the movement of the locomotives between the table and the house and over the locomotives in the house; and the coaling plant, ashpit and other accessories are handled by the transportation department. In other organizations the engine house official has supervision over the entire engine house premises, including the coaling plant, ashpit and all other accessories.

7 It is not well established which is the better organization, and not only does the organization differ on different roads, but often the same road has changed several times from one arrangement to the other. It is probable, however, that the best arrangement is the one which provides the highest class official nearest to the place to be handled. The best results probably will be obtained from the present tendency to place a master mechanic at each of these important locomotive terminals and assign to him supervision over the entire plant. Such an arrangement will place the line of separation of responsibility for incoming locomotives on the approach to the engine house and outside of the coaling plant; and for outgoing locomotives at the track assigned for locomotives ready for service.

SEPARATION OF LOCOMOTIVES ON A DIVISION

8 On a division having only one important locomotive terminal it is not necessary to designate where the important repair work will be done, but on many divisions there are two or more engine houses thoroughly equipped for the complete maintenance of a certain number of locomotives, and on these divisions it is necessary to designate those which will be maintained at each house. Each engine house will do the periodic work and the running repair work on the locomotives assigned to it, and the inspection and safety repair work on any locomotive which is run into the engine house. The assignment of the locomotives to the different houses is made by the divisional mechanical officer, usually designated as master mechanic. There is more or less transference of locomotives from one division to another for temporary service, but there are serious objections to this, especially when the periodic work and reports are to be considered, and when the duration of the temporary service is more than a few days. On the large railroad systems it seems quite necessary that an individual locomotive record of periodic inspection and work be kept by the divisions and the transferring of locomotives from one division to

another for a week or two results in annoyances, errors and loss of records incident to transferring records when the locomotives are transferred.

LAYOUT OF A LOCOMOTIVE TERMINAL

9 It is not the intention of this paper to cover this item in such detail as would be necessary for the preparation of an ideal layout, but rather to deal in generalities which may be of greater interest in an international discussion. It will be in order to consider, first, the capacity of the various facilities which are to be supplied. It is desirable to rate the capacity on the maximum demand for a comparatively short interval of time, say one hour or two hours, for the coaling, ashplant, turntable, water and sand facilities; and for longer periods of time for other facilities. Some of these ratings may be consistently higher than the sustained rating of 24 hours. There should be considered also, how much of the terminal will become inoperative in case of accident to any one of the important units of the terminal, and the approximate length of time the resulting disorder may continue; and to provide the necessary assurance of continuous operation, by the installation of duplicate units. The water and coal plants and the turntable are the most important units and these will need special study.

10 Water columns are usually so well distributed at a division terminal that only a failure of the entire water system need cause much delay, so that the important consideration is convenience of location. The insurance may be taken care of in the general water system. An ample supply of water is also of prime importance.

11 For insurance of the coaling operation there may be selected one of several schemes, one of which is to place the cars of coal on one, and the locomotives on another of two or more adjacent tracks, transferring the coal from the cars to the tenders by hand or by locomotive crane. Another scheme is to coal the locomotive at the coal-stocking plant, if one is near by; or by other means, none of which seriously affect the general arrangement of the locomotive terminal.

12 On the contrary, insurance of turntable service will very decidedly affect the general layout of the terminal because the spare table must be capable of serving the whole or a considerable part of the engine house capacity, inasmuch as failure of one table may occur when a large number of the locomotives are in the house served by it.

The only way in which more than one turntable can serve one unit of engine house capacity, in a circular engine house, is by dividing the house unit into parts and having a turntable for each part. To accomplish this result it is considered very good practice to limit the size of a separate engine house to approximately a half-circle, and to provide any additional capacity in another half-circle, offset from the first at least enough to permit of a separate turntable for each. The separate turntables should have track connections to the inbound and outbound tracks, and usually have inter-connecting tracks.

13 For further insurance of uninterrupted turntable operation two motors for revolving each turntable are considered desirable, and even necessary, but both should not be operated from the same power plant. Sometimes two gasolene motors are used, and sometimes one electric motor is provided for general use and a gasolene motor for emergency use.

14 If the house is made up of parts of two circles, one end of each part will be placed near one end of the other, and the machine shop, storehouse, power house and offices will drop in very naturally between the two. The drop pits, overhead crane, and other special facilities necessary in a limited section of the engine house, will be placed convenient to the shop.

15 There remain to be located only the coaling plant, ashpit, sand house and water columns, which will be placed primarily for convenience in getting the inbound locomotives to them. There must be ample water facilities on the outgoing tracks and it is desirable to have a small ashpit and a sanding place on these tracks. If provisions are made to get the outgoing locomotives to the coaling plant on special occasions, then a coaling place is not necessary on the outgoing track. Of these facilities on the inbound tracks the ashpit will be nearest the turntable so that the locomotives may be moved the shortest distance when there is little or no fire on the grates. Sometimes it has been thought desirable so to arrange the facilities that coal, water and sand can all be taken at the same time; but if the hostler is to stay in the cab so as to be ready for moving the locomotive promptly, it is probable that the difficulty in arranging these facilities for the various lengths of locomotives will make it desirable to place them somewhat more than a locomotive length apart if the ground space permits. Sometimes a track arrangement is made that permits of advancing one or more locomotives around other locomotives, and when the ground space is available this is a good thing to do. The tracks on which the ash

cars are taken to and from the ashpit should be independent of the inbound and outbound locomotive tracks.

THE ENGINE HOUSE

16 The cross-section and other details of construction of the engine house have such important relations to the prompt handling of locomotives at terminals, especially in the colder climates, that it is well worth while to refer to them.

17 The two items which have been given most consideration during the last few years, for houses located in the colder climates, are the heating and the ventilating; they are so closely related that they should be considered together. For low cost of heating, the area of the cross-section should be as small as the locomotives will permit and until recent years it was the practice to follow this principle in the design. Unfortunately, good ventilation, which is equally important, has not been obtained with the small cross-area and as a result the condition of fog and smoke, and principally fog, in these low-roofed houses in cold weather is such, at times, as scarcely to be understood until seen.

18 A decided improvement in ventilation has resulted from raising part of the roof somewhat higher than the necessary headroom would require, placing the ventilators at the top of this higher portion. The design of these ventilators is undergoing a process of development and at present practically each road has its own preferred design. An advantage of this high roof section is that additional area for windows is given in the enclosing wall, and this additional lighting is important for the wider houses now necessary.

19 In the effort to reduce to a minimum the fog in the house in cold weather, special efforts are also made to prevent the escape of steam from the locomotives. To this end a pipe line of large diameter is placed around the house, usually above the locomotives, with terminals conveniently arranged for making quickly a pipe connection to a valve in the top of the boiler. To reduce the steam pressure in a boiler the steam is blown through this pipe into the atmosphere, or to water-heating tanks or hot wells.

20 Pipe lines, including cold-water, hot-water and steam lines, are similarly arranged for washing out boilers, and provision made for mixing the cold water with hot water or steam to get the desired temperature for washing. The same pipe lines, or others, conduct the water from the boiler to storage tanks and reheaters. The smoke-

jacks have elongated bases which cover the safety valves as well as the stack.

21 The heating is done by one of two methods: by direct radiation from steam pipes placed on the side walls of the pits; or by hot-air blast. Probably the latter is preferable. The place of delivery of the heat is as near the locomotive as possible. The capacity for the steam heating is usually all that can be obtained from two to six 2-in. pipes on each side wall in the pit and some on the outer wall of the house; for the hot-air system the capacity is the volume of the house every ten to fifteen minutes, at a temperature of about 60 deg. fahr. A very important point about heating engine houses is to keep the doors and windows closed and to cover the usual openings at the bottom of the doors. It is desirable also that the roof timbers be so placed as not to interfere with the flow of air upward along the roof to the ventilator outlets.

22 It is the general practice to provide several tracks in the house, with a drop pit into which to drop driving and truck wheels, and to provide in the same section of the house an overhead crane for loading to and unloading from cars these wheels, and for handling air pumps, cabs, boiler fronts and other heavy parts to and from the locomotives. Light portable cranes are provided for lifting steam chest covers, rods, and other heavy parts which do not require high lifts.

23 There are many smaller details about engine house design and equipment which contribute to the rapid and efficient handling of locomotives, but it will be best not to burden the paper with them.

THE COALING PLANT

24 The uninterrupted operation of this plant is of prime importance, and with this in mind, that design should be chosen which is least liable to be deranged and which can be repaired most quickly. With sufficient ground space available, these considerations will make the choice a trestle, so that cars of coal can be pushed or hauled up an incline and the coal dumped direct from the cars into the bins from which it slides by gravity into the locomotive tender. This kind of plant reduces to a minimum the breakage of fragile coal, sometimes an important feature. If the incline approach is too steep for steam locomotive operation, the motor and winch should be in duplicate and the motors not dependent upon the same source of power, unless there is little chance of total disability of the source.

25 When the ground space is limited the mechanical hoisting plant, of the bucket or a similar type, is a necessity, and it has been selected sometimes when the available space would permit of a trestle. There are various forms of the mechanical plant, but it will be unnecessary to consider them in detail. Usually they are placed crosswise of the tracks. Sometimes the same apparatus used to elevate the coal is used to convey ashes from the pits and to deliver them into storage bins or into cars. This combination has the advantage of concentration of facilities when such concentration is necessary, but there are objections to it otherwise. To give the necessary capacity at the coal pockets and ashpits a greater number of tracks are necessary and the risk of personal injury from coal falling from the tender and striking the men who must be about the ashpit is increased. This concentration will shorten and widen the approach to the engine house.

THE ASHPIT

26 It is desirable to have a pit capacity immediately beneath the locomotives for several hours' busy dumping of pans and grates, whether the ashes are handled by hand or by machinery from the pit to cars. If handled by hand this is to provide for economical time distribution of labor; if handled by machinery, to provide for continuous dumping when the machinery is out of order. The economical transferring of ashes from pit to car by hand requires a lower pit for the ash cars, adjacent to the ashpit, and sometimes conditions do not permit of such an arrangement or of the necessary track approach. If the ash pan and fire cleaners can be used for transferring the ashes from pit to car, at intervals when there are no pans or grates to be cleaned, the manual labor can be most economically distributed. The mechanical plants usually operate crosswise of the pit, limiting the length of pit undesirably, and making necessary several pits side by side or a further mechanical installation for transferring the ashes lengthwise of the pits to the cross conveyor. With each addition to the mechanical devices, complications are multiplied. Water hydrants for hand hose are located conveniently about the ash pits, and shelters are provided near by for the men to occupy when there is a lull in the work.

THE SANDING PLANT

27 The sand-drying plant should be located convenient to the inbound tracks, but not necessarily adjacent to them. Convenience

in delivering wet sand to the drying plant is important. As air pressure is used to elevate the dry sand to the storage bin from which it falls by gravity to the locomotive sand box, air pressure can also be used for transferring the dry sand for some distance horizontally, so that the place of delivery for the wet sand may be conveniently located for such delivery. Sometimes the sand is dried on steam-heated tables, but since the temperature cannot be raised high enough for satisfactory drying, the preferred dryer is the stove. The dry sand bin, from which the sand is delivered to the locomotive, is usually located between the coaling plant and the ashpit.

WATER SUPPLY

28 Water columns should be conveniently located on both inbound and outbound tracks.

THE ORGANIZATION

29 *The Master Mechanic.* The usual divisional organization places one man, the master mechanic, in charge of the locomotives on the division, both when the locomotives are away from the engine house and when at the engine house. One of the division terminals is under his supervision and his headquarters are generally at that terminal because it is the important point of his jurisdiction. He may have assistants with duties both at terminals and between them, and he always has assistants, called assistant master mechanics, who confine their efforts to the terminal, and others who confine their efforts to the road work. If at the divisional terminals the freight locomotives and the passenger locomotives are separated, as is often the case, one assistant may have supervision over freight locomotives and terminals, another over passenger locomotives and terminals, and a third over the intermediate division engine houses, in which both passenger and freight locomotives may be cared for.

30 *Traveling Foremen.* The assistants in the operation on the road are usually designated as traveling engineers or road foremen of engines, and traveling firemen. Some are assigned to passenger service and others to freight service, and they report to the master mechanic, or if there are assistant master mechanics, then to the proper assistant master mechanic. Their duties are, nominally, to instruct the engine drivers and the firemen; to report the conditions of the locomotives as delivered from the engine house; to foresee, when possible,

and to report work on the locomotives which may require special preparation or special attention for the preparation of material, etc. Too often, and it may be said usually, they are kept busy ascertaining and reporting what has already happened and explaining it, whereas their efforts should be directed to preventing the repetition of undesirable occurrences. It is conceded, however, that a general knowledge of what has happened and the causes is essential for the intelligent direction of means for preventing recurrence.

31 All of these officials, from master mechanic to traveling firemen, are subject to call at any hour.

32 *Engine House Foremen.* The organization at the locomotive terminal will begin with the general foreman, who will have general supervision of the terminal 24 hours a day and seven days in the week. He will have personal supervision in the daytime; the assistant general foreman will report to him and have supervision at night. These two may arrange between themselves, subject to the approval of the master mechanic or the assistant master mechanic, for regular rest days. The division of the 24 hours between these two men means somewhat more than 12 hours a day service for each, that there may be time for the necessary consultation between them. Because of this and the fact that the change in supervision is made in the morning and evening, the busiest hours at most engine houses, and at about the same time the other employees change shifts, there is being considered, and in fact put into operation at a few places, an arrangement for 8-hour shifts, so assigning the terminal men that the entire shift will not change at any one time. In such an arrangement the general foreman would be present during a part or the whole of every shift and one of his three assistants would be assigned to each shift. Twenty-four-hour operation is necessary at engine houses and two complete breaks in each 24 hours are not conducive to best results, nor can a man deliver his best efforts for 12 hours a day continuously. Hence the tendency to shorten the hours of daily service and to minimize the effect of each change of shift.

33 In addition to the assistant general foreman, the store-keeper and chief clerk will also report to the general foreman. To the assistant general foreman in charge of each shift, the yard foreman, the house foreman, the shop foreman, the foreman of laborers, the despatcher and the necessary clerks, will report.

34 *The Yard Foreman.* He should have complete charge of the locomotives at the terminal and outside of the house. He should take from the house foreman instructions as to the particular stall in which

each locomotive is to be placed and report as soon as it is placed; and should take from the despatcher instructions about delivering the locomotives to the transportation department. This arrangement will place under the supervision of the yard foreman, the coaling, sanding, watering and ashpit plants, and the turntables; the care of the locomotives which are standing outside of the house; and also the special crews that run the locomotives between the engine house and the train terminal, when such crews are necessary.

35 *The House Foreman.* He should have supervision over the workmen in the house, and over the inspectors on the incoming track, if there are such inspectors. The various foremen reporting to him are those in charge of repairs to tenders, boilers, machinery and air brakes, and others similar, depending on how far the work is specialized. In working out the 8-hour shift arrangement, it has been suggested that there be assistant house foremen, each with supervision over certain stalls assigned to him; the special work, however, such as air brake and similar work, to be done by special gangs for all the stalls. The shop foreman will also transfer machinists, boiler makers, etc., from one assistant foreman to another, as conditions may demand. This arrangement of dividing the house into sections, each in charge of an assistant foreman, is being used with satisfactory results. It makes of the assistant foreman a high-class inspector because it places him in such close touch with the conditions that he can say just what work should be done, and know how thoroughly it is done. This is a most important consideration because the engine men and inspectors may report a lot of work to be done, partly to clear themselves, as well as to inform the foreman thoroughly. The man who does the inspecting and repairing on a locomotive or on a number of locomotives day after day, is well informed on what must be done and how it should be done; which leads to the suggestion of the further step that the maintenanck of certain locomotives be assigned to certain gangs. This ought not to be impossible in passenger locomotive terminals.

36 *The Shop Foreman.* The importance of the shop foreman depends largely upon the importance of the shop. Sometimes his duties are assumed by the engine house foreman. The tendency seems to be in the direction of providing larger shop facilities, and as these are increased the importance of the shop foreman will increase.

37 *The Work Report Clerk.* The clerical force perform the usual duties of such employees. There is one clerical position, however, which is growing in importance and the qualifications for the filling of which are becoming more and more exacting; this is the position of

work report clerk. He should understand clerical work and know enough about locomotive parts and repairs to make out a satisfactory report of work to be done. He first comes into contact with the arriving engineman, who reports on conditions which can be observed only when the locomotive is in action. Enginemen do not like to write, hence their written reports are short and unsatisfactory. The tendency at present therefore is for the clerk to write these reports for the signature of the engineman and the clerk must understand what work is necessary and report it properly. As the clerk is almost always accessible, the information is thus available in case further explanations are required. This clerk also makes a record of the incidents of the trip as reported by the engineman, so that in case of inquiry, the desired information is already on file.

38 The engineman's report of work to be done and the report of the inspector should reach the work report clerk at the same time, that there may be no delay in distributing the work to the respective gangs.

39 *Bulletin for Completed Work.* Quite as important as having the work to be done promptly reported to those who are to do it, is the reporting back promptly when the work is completed, and to have this information easily available for those who need to have it. For this purpose various arrangements are provided, the details being worked out to suit the peculiar layout of each house. The essential features are provided by a blackboard located conveniently for those who make the records and for those who must read them. This board is ruled into vertical columns, one for the number of the locomotive, one for the number of the stall in which the locomotive is located, and other columns, depending upon how the work in the house is distributed among the repair men. For instance, there may be a column headed "air brake," another "boiler," another "machinery." As each class of work is completed each foreman marks on the board in the proper column and opposite the particular locomotive number his "O. K.," indicating that his work on the locomotive has been completed. When all the spaces opposite a locomotive number are marked "O. K.," it is evident that the locomotive is ready for service. The record is erased as soon as the locomotive is taken out of the house. The convenience and despatch with which these records can be made are important factors.

40 *Outfitting the Locomotive.* Contrary to the previous practice of requiring the locomotive crew to do some cleaning, fill oil cups, and in general look after the outfitting of the locomotive, the present ten-

dency, and it is pretty well established, is for the engine house force to outfit each locomotive completely for service on the road. There remains for the crew, of course, the responsibility to know that the necessary repairs and outfitting have been done, even though the locomotive is delivered to them at the station.

41 *The Despatcher.* It remains for the despatcher to know what locomotives and crews are arriving, and to care for the proper despatching of locomotives and crews

POOLING.

42 Some years ago it was the general practice to assign a locomotive to a crew and both crew and locomotive to particular runs, and when the locomotive was taken to the shop for repairs the crew worked in the shop until the repairs were completed, usually devoting much, or all of its shop time to its locomotive. At that period there were few extra passenger runs and the freight runs were very largely scheduled runs, under which conditions it was easy to assign locomotives to crews and crews to runs, keeping each crew on its particular locomotive and run. As the maximum freight service increased and the fluctuation between maximum and minimum freight service widened, it became necessary to move a large proportion of the freight trains as extras, which made it quite impossible to assign crews and locomotives to runs not scheduled. It was also necessary to increase or to decrease the number of locomotives in proportion to business demands, which could be done only by withdrawing locomotives from service, during which time there would be only the interest and depreciation charges on them.

43 As a result a plan was developed to increase the service of the locomotives by placing any crew on any locomotive for service, instead of holding it until its assigned crew could obtain the necessary rest. While this prevented the assignment of locomotives to crews it made possible a larger individual locomotive mileage per month or per year. The first experience with this arrangement in freight service seemed so satisfactory that it promised well for passenger service to which it was extended, so that a locomotive used one day on one train would be used the next day on a different train, permitting the operation of a certain number of trains per day with greater or less number of locomotives than trains. The idea, of course, was to operate a number of trains with a less number of locomotives.

44 The criticism most generally made upon this system is that the personal interest which the man had originally in his own locomotive is lost. This has been valued very highly by some officials, more particularly those of the motive power department, and less

highly by others, usually of the transportation department and more particularly those who are not so well versed with the trials and tribulations of the motive power department. Under the pooling system the effort of the average crew is to get through with the particular locomotive as quickly and as easily as possible and to let the next crew get along as best it can.

45 Such conditions necessitate careful watching of the reports from the enginemen so that everything that the engine house inspector cannot well find is included, and also careful inspection and repairing at the engine houses. It may make necessary also, an additional expense per locomotive for wear and tear, as some argue, and at the engine houses, as others argue; but whatever the cause or amount, this additional expense is the cost of getting the additional mileage per locomotive per month or per year, and it is a question of whether the cost is more than offset by the gain. The argument that it is as well to get the mileage-life of a locomotive in fifteen years as in ten neglects the fact that possibly 50 per cent more locomotives will be required if it is gotten in fifteen years than if in ten years, with a resulting interest charge.

46 Possibly, also, those who hearken back to the times of assigned locomotives and crews and picture to themselves the enginemen setting box wedges and rod brasses, adjusting the piston rod packing and doing a long list of other work overlook the difference in the size of the parts of present and past locomotives, and that a crew even if it knew a certain work was required and was willing would be unable to do it, at least alone. Extensive experiments have been made to determine the relative costs of the assigning and the pooling systems and in some of these experiments at least, no material difference in cost has been found. However, there may be, and probably is, some loss in reliability of service in pooling.

47 The fundamental idea of pooling is to obtain from each locomotive the maximum mileage per month or per year, in other words to keep the locomotive going, and various schemes have been devised to accomplish this and to obtain at the same time any advantages there may be in the personal interest of a crew in its own locomotive. One of these is to assign one locomotive to two or, at times, three crews, each crew making a round trip from terminal to terminal. A variation is to change the crews about midway in the trip; this has some decided advantages, the principal one being that a fresh crew is obtained at the beginning of each quarter of a round trip, or each half of a single trip, and while the rest at each terminal is not of long

duration, yet it means much to the crew, especially in hot weather; also, inasmuch as the crew is not at home at the divisional terminal, the men are anxious to start back so that they may reach home. To work out satisfactorily this system of changing crews at the middle of a division, it is necessary that the divisions be so arranged, or of such length, that there shall not be too much constructive mileage for the crew; that is, that the mileage for which the crew is paid shall not be materially less than the actual mileage made by it.

48 Since it is quite certain that a locomotive in proper condition for service can be used a greater number of miles or hours per week or per month than one crew is able to stand, it would seem to be good policy to get full returns in some way and not limit the output in miles or in hours service to the capacity of the crew; on the other hand, the men must be given proper consideration and be permitted to make fair wages. The pooling of locomotives and of crews in the different kinds of service makes it possible to use each locomotive the maximum number of miles in a certain period of time, which maximum will be about the same as for any other locomotives in the same service, granting, of course, that nothing serious goes wrong with it; it also makes possible maximum and equal earnings by men of physical equality.

49 The assigning of one locomotive to one crew limits the output obtained from the locomotive during a month or a year to the capacity of the crew; assigning one locomotive in road service to two or more regular crews need not limit the output of the locomotive but may place the earnings of the crew below its ability and below average earnings for similar work. In yard service it is possible and is the general practice to assign one locomotive to two crews. If in road service one locomotive is assigned to two or more crews, the run should be arranged to permit each crew fair earnings. Another variation of the pooling system is to assign two locomotives to three crews, to which resort may be made when two crews on one locomotive cannot make the average earnings.

50 It will be noted that the original idea of pooling was to obtain maximum mileage from the locomotives, which resulted, apparentlly, in taking from the crews and placing upon the engine house a large part of the responsibility of the condition of the locomotives; then appeared variations which had in view this original idea, coupled with the effort to place upon the crews at least a part of the responsibility for the condition of the locomotives taken from them or voluntarily given up by them under the straight pooling system; each arrangement having in mind a fair earnings return to the crews.

ENGINE HOUSE PRACTICE

OR THE HANDLING OF LOCOMOTIVES AT TERMINALS TO SECURE CONTINUOUS OPERATION

By F. H. Clark,[1] Chicago

Member of the Society

The topic assigned me is so comprehensive as to embrace nearly all features of engine house practice. In order to get the matter clearly before the meeting, therefore, it may be desirable to describe briefly such features of design and equipment as are considered good practice in the United States.

ARRANGEMENT OF LOCOMOTIVE TERMINALS

2 The engine house and its appurtenances should be located, when possible, at a point near the yard or station where the engines are released or required, though the plan must usually be adjusted to meet existing conditions of topography or space. In Fig. 1 is shown a plan which may serve as a basis of the paper. It has no unusual features, but it may be considered a fair example of engine house practice. Some space might be saved by the use of a different design of cinder pit, and considerable space by a different coaling station. Other modifications would naturally suggest themselves in considering the application of the plan to any specific case.

3 The approach to the engine house provides two tracks for incoming engines, one on either side of the coaling station, and one track for outgoing engines; though connections are provided by which the movement may be varied if necessary.

4 The coaling station indicated on the plan is of a design frequently employed in locations where space permits. Fig. 2 shows its

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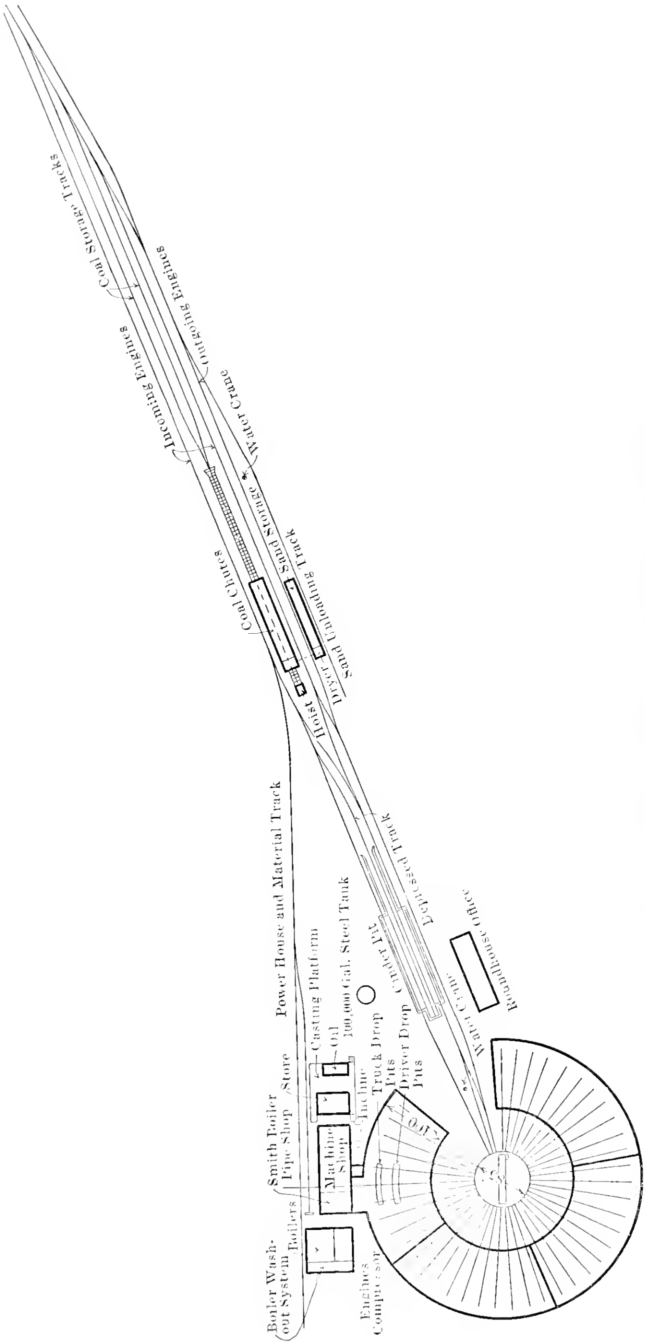

Fig. 1 Arrangement of Locomotive Terminal

general construction, but with the tracks at right angles with the center line of the structure, instead of parallel to it, as in Fig. 1. The coaling station illustrated is of 700 tons capacity. The coal is elevated in cars by means of a hoist which pulls the loaded cars up a 20 per cent incline at a rate of about forty feet per minute. The coal is shoveled or dumped out of the car directly into bins or pockets, if breaking is unnecessary; or on a grating of breaker bars spaced four to six inches apart, through which the coal drops when broken. The

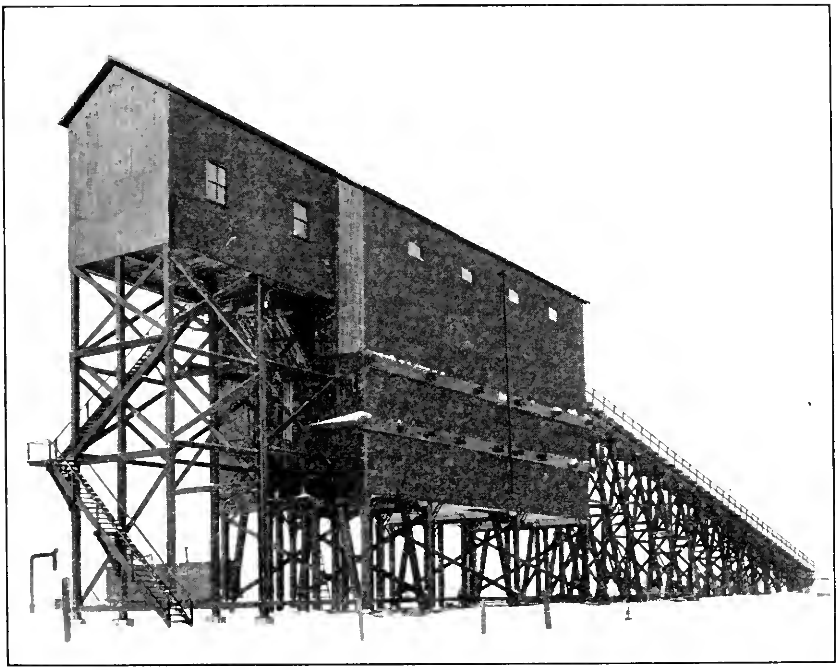

Fig. 2 Coaling Station with Trestle

station delivers coal to six tracks, five underneath and one at the end. The hoist may be operated by steam or gasolene engines, or by electric motors, motors being usually considered preferable where electric current is available.

5 Another type of coaling station is shown in Fig. 3. This station has an overhead storage capacity of 1200 tons, and the construction is entirely of steel and concrete. The coal is hoisted in a pair of Holmen counterbalanced buckets, and distributed in the bin by means

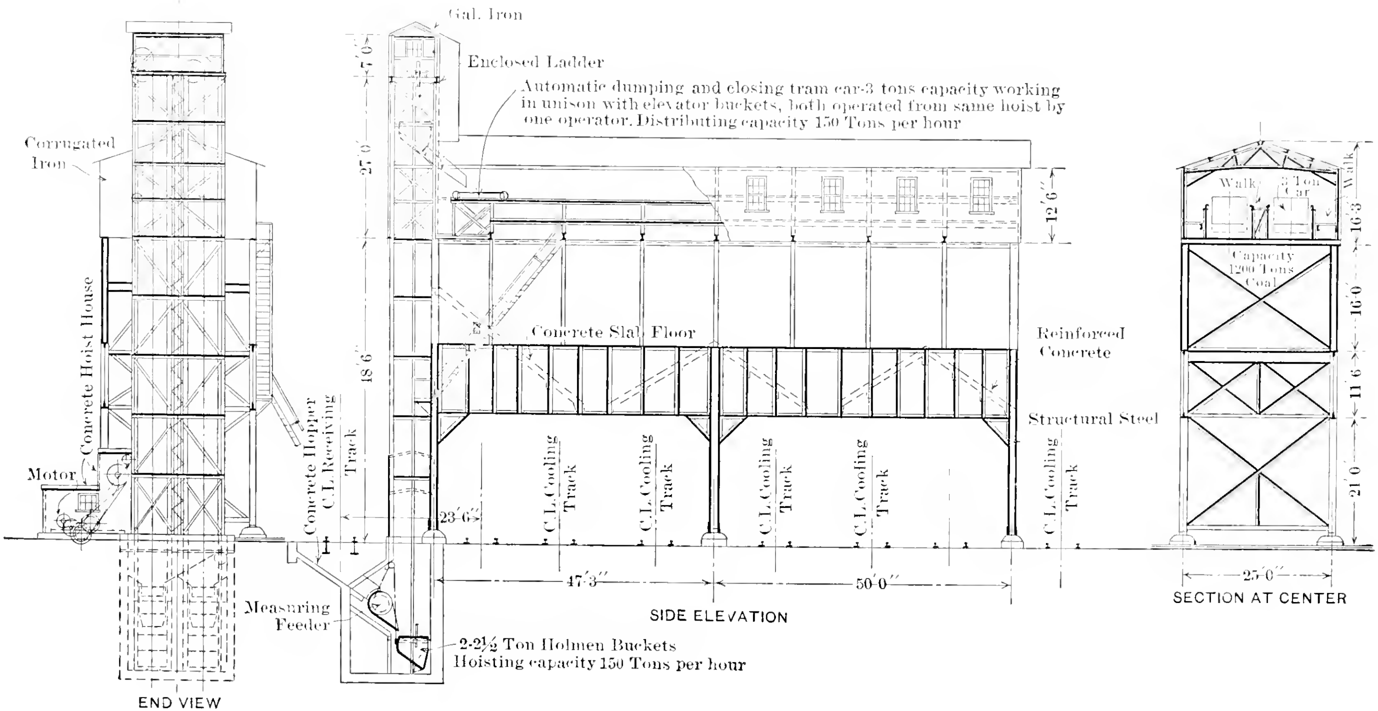

FIG. 3 COALING STATION WITH BUCKET ELEVATOR

of a special automatic tram car. The coal is received at one side of the bin and is delivered to five coaling tracks, four underneath the pocket and one adjacent. To facilitate the handling of cars of coal during the winter, three additional receiving hoppers are provided, so that coal frozen in the bottom of the cars may be removed without interrupting the main hoist. The coal is then transferred from the three hoppers to the main hoist for elevation to the overhead pocket. This plant is operated by electricity.

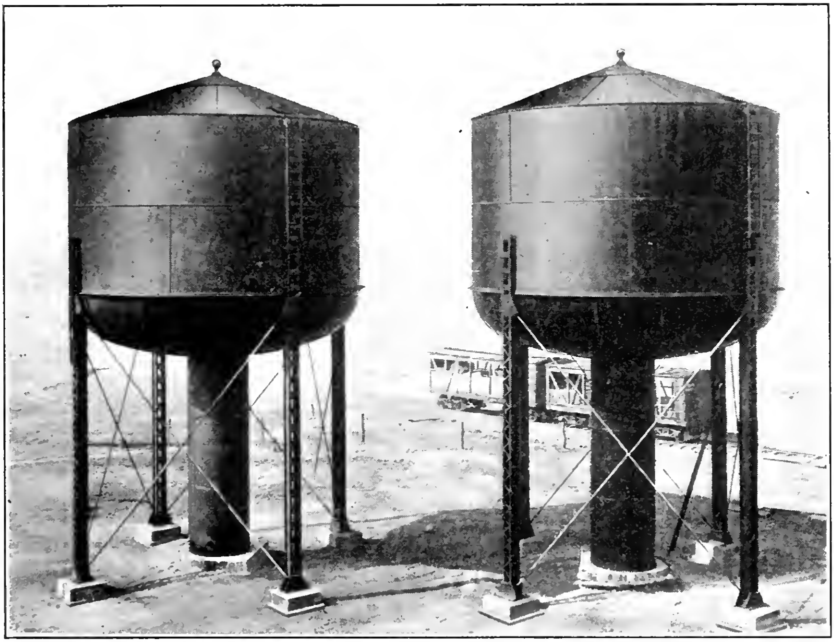

FIG. 4 100,000 GAL. STEEL WATER TANKS

6 Various other types of coaling plants are in successful use, the coal being elevated by belt conveyors or small bucket conveyors, or handled by cranes of various types, with clam shell or similar buckets. The cost of operation ranges from two to ten cents per ton, depending upon various factors.

7 The sand-drying apparatus shown in Fig. 1 is placed opposite the coaling station, though frequently a part of the coaling plant is used for that purpose. One of the most common methods of drying

sand is by coal stoves, which differ considerably in design. The moist sand is delivered from a hopper to a casing surrounding the stove, from which it escapes as it becomes dry. Some of the more modern sand-drying houses use exhaust or high-pressure steam from the power house. After drying, the sand is usually hoisted, by means of compressed air or by some form of conveyor, to a storage bin, from which it is drawn by locomotives when needed. Rotary sand-dryers, in which sand is fed into an inclined tube through which a current of hot air passes, are not commonly used, but could no doubt be used to advantage if a considerable amount of sand were required.

8 The water supply for locomotive use is usually stored in overhead tanks of various capacities. Fig. 4 shows two steel tanks of 100,000-gal. capacity recently erected. The body of the tanks is unpro-

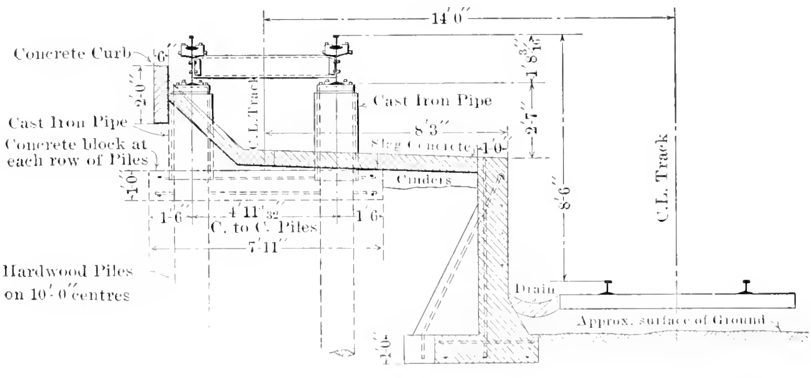

FIG. 5 HALF SECTION OF ELEVATION CINDER PIT

tected from the cold, but the connection between tank and water mains is usually enclosed, as shown, in places where freezing is likely to occur. Standpipes, or water cranes, are so placed that water may be taken without backward movement. Ten-inch cranes are frequently found in modern installations. These will deliver 2000 to 3000 gal. of water per min. under usual conditions.

9 Cinders and clinkers from incoming engines are handled in various ways. An arrangement in common use which has proved very satisfactory is shown in Fig. 5. The contents of the ash pan are dumped on a platform about four feet below the top of the rail, with a slight incline toward a depressed pit into which cars are run for load-

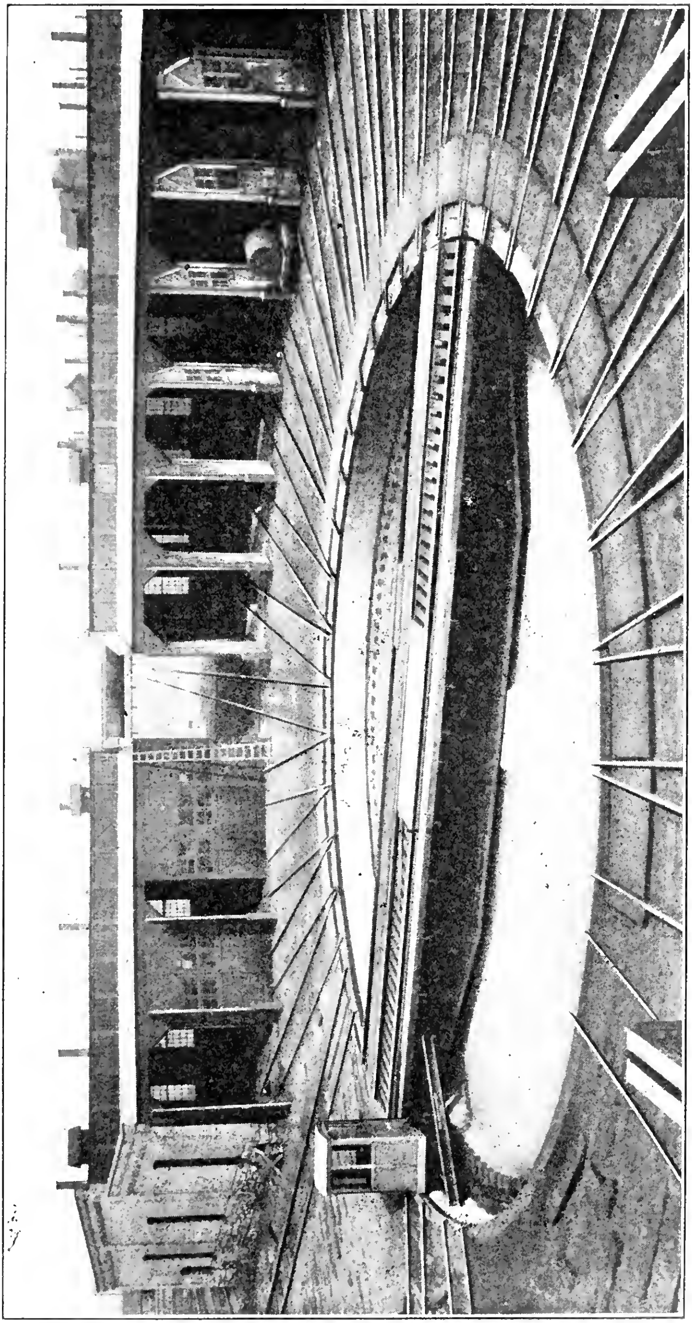

FIG. 6 MOTOR-DRIVEN TURNTABLE

ing. In Fig. 5 the rails are shown supported on wooden piles, the upper ends of which are surrounded by cast-iron pipes, with insulating material packed between the pipe and the pile. The use of concrete piers is considered preferable where foundation conditions will permit. The cinders and clinkers removed from the ash pan are wet down and shoveled into an open coal car standing in the depressed pit. With engine tracks on each side of the pit, several engines may be accommodated at a time, and the plan affords considerable storage capacity, so that, with a pit of moderate length, a day force of shovelers is sufficient to take care of the accumulation.

10 In some modern plants the slope from the outer rail delivers the refuse from the ash pan into a concrete pit about eight feet in width and depth and filled with water. In this case the material is removed by means of a traveling gantry crane with clam shell or similar buckets, and delivered to cars standing on the side of the pit opposite the engine. In other cases pits are provided between the rails, in which buckets are placed, and the buckets are lifted out and the contents deposited in open cars by a gantry or ordinary overhead electric-driven crane with elevated runway.

11 The engine houses of the United States, usually being circular in form, require turntables for the delivery of engines to and from the house. A common length of table for new installations is 80 ft., though a great many shorter tables are still in service, and working satisfactorily where the length of engines is not too great. Turntables are frequently moved by hand, though a more economical method, where a considerable number of engines are turned, is by tractors driven by gasolene engines or electric motors. Fig. 6 shows the application of such a tractor to a turntable. The tractor has a heavy steel frame of triangular shape attached to the turntable by means of hinges at two points, the weight being balanced on the single tractor wheel traveling on the circular rail in the pit. On this frame are mounted the motor, gearing, bearings, shaft and brake, comprising the driving mechanism. Above the machinery, and entirely covering it, is mounted the operator's cab, in which the operating mechanism is located. Electric motors are generally considered preferable where current can be provided uninterruptedly, and on such installations a collector device is applied to the turntable center. This maintains a connection with the feeder line, which is brought underground to the center of the pit, though, in case the pit is subject to flooding, an overhead collector may be used.

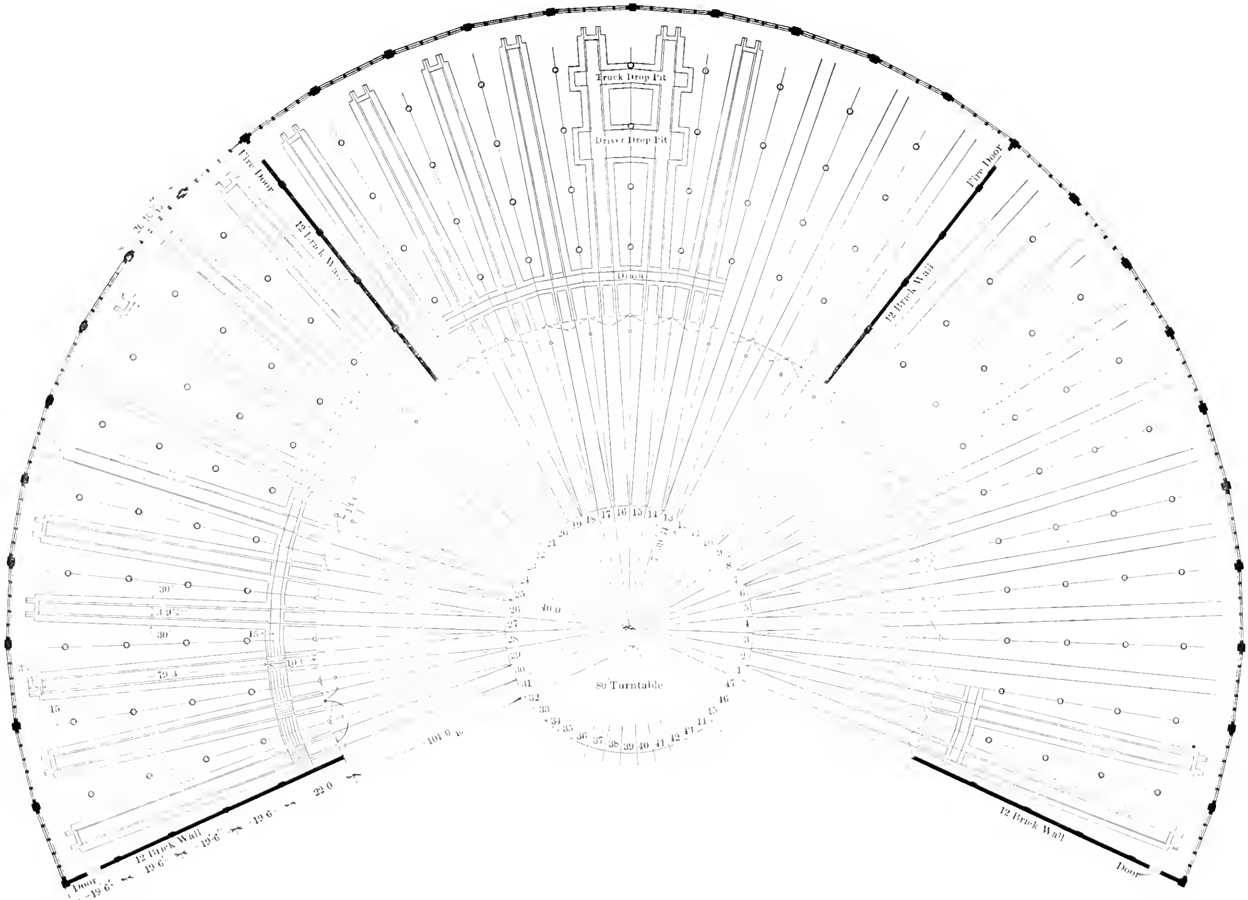

Fig. 7 Plan of Engine House with 30 Stalls and Provision to Contain 47 Stalls

THE ENGINE HOUSE

12 Fig. 7 shows the plan of an engine house with thirty 100-ft. stalls and an 80-ft. turntable, on a circle having a maximum provision for forty-seven stalls, including inlet and outlet tracks. This plan shows fire walls separating the house into three rooms of ten stalls each. The two center stalls are provided with drop pits, by means of which driving and truck wheels may be removed and replaced without jacking up the engine. The engines in this house are intended to be headed in and backed out.

13 Reinforced-concrete framing is frequently employed, though the roofs are generally of wood and covered with tar and gravel. The use of exposed iron or steel in roof construction is generally avoided because of the rapid corrosion. The pits are connected at the inner ends by a drain from which the water escapes through an outlet sewer emptying into a large catch basin, or sump, where the sediment is deposited.

14 The pits in this case are recessed for steam-pipes, though the use of fan blast for heating engine houses is becoming more and more general, and it is usually found that better results are obtained by the use of vitrified tile ducts laid underground and discharged into the sides of the pits, than by the use of galvanized pipes above ground, which generally need frequent renewal. An important advantage of the fan blast is that it assists in ventilating the house, changing the air in from eight to thirty minutes, as usually installed and operated.

15 There are a great variety of smoke jacks in use. The type which seems to be coming into favor, is conical in shape and is frequently made of wood, lined with sheet asbestos or similar material. Smoke jacks are generally provided with dampers in houses where fan heat is used, and a space is sometimes left open around the jack for assisting in ventilation.

16 The satisfactory lighting of engine houses is a difficult problem. Oil, gas and electricity are commonly used. Incandescent lamps do very well if kept clean, and have the advantage of portability, separate circuits being frequently provided for extension cords, so that light may be carried to any point where it is needed.

17 Floors of vitrified or paving brick, crowned sufficiently to drain to the pits, have been found very satisfactory.

18 Drop pits for the removal of driving and truck wheels are very convenient. They are frequently made to span three tracks and of width sufficient to take the largest wheel handled. The jacks used

in these pits are generally mounted on carriages, running on rails laid in the pits, and they are usually operated by air or water, though screw jacks are sometimes used. Hydraulic jacks are usually considered preferable to air jacks because of their more positive action. Cranes are generally provided over drop pits.

19 The shop facilities necessary at the engine house depend upon the distance from large repair shops. Generally speaking, the tool equipment should be sufficient to take care of running repairs, though if the house is located near a repair shop some of the machinery that would otherwise be necessary may be dispensed with. There should also be a tool room, conveniently located with respect to the machine shop and engine house, in which small tools of all kinds can be conveniently kept and drawn as required. The storehouse should be similarly located and should carry a sufficient amount of material to handle the repairs frequently necessary.

20 There is nothing of particular interest to be said about the power plant of the average engine house. Boilers, engines and other equipment may be of any type desired. It seems to be the custom to figure on about ten boiler horsepower per stall and, on account of the common use of air tools, a compressor capacity of about 20 cu. ft. of free air per minute per stall is usually provided.

21 Oil houses are generally of fireproof construction, with the oil stored in a separate room from the place of distribution, from which it is drawn or pumped from tanks as required. The oil is usually stored in tanks in the basement, the size and number of the tanks depending upon the amount and variety of oils used. Self-measuring pumps are extensively used in modern installations.

22 Of recent years there has been considerable demand for better and quicker methods of boiler washing, and as a result several systems have been introduced. One of the earlier arrangements consists of an open cistern of perhaps 100,000-gal. capacity, located near the engine house. In this the steam blown off from locomotives is used for heating water to wash out the boiler, and in some cases also for heating fresh water with which to refill it. Recent installations are the National, which is of the closed-heater type, in which the steam and water blown off are used for washing out and for heating fresh water; and the Raymer system, which is of the enclosed-heater type and performs similar functions. Blowing-off, washing and filling connections are generally provided between alternate stalls in the engine house.

23 Locker rooms are generally provided for engine men, and fitted

with a sufficient number of expanded metal lockers to accommodate their clothing and small tools. These are located in a building near the engine house office. Lockers are also provided for shop men, and are frequently located inside the engine house on the walls of the building. The lockers are generally made of sheet steel with openings for ventilation. At points where boarding and lodging houses are not conveniently accessible, bunkhouses are frequently provided for the accommodation of the enginemen. These are usually provided with toilet rooms, shower baths, etc.

THE ENGINE HOUSE ORGANIZATION

24 The details of handling engines vary greatly on different roads. It seems to be generally customary, however, to have the engineer relieved at the coaling station by a hostler, though at some plants inspection pits are encountered before the engine reaches the coaling station, and the engineer is relieved at those points. In some cases also the cinder pits are reached before the coaling station, though it is generally considered better practice to have the cinder pits next to the engine house, so that if the fire is dumped the engine will have but a short distance to travel and encounter but little delay before reaching the house. The hostler, however, takes coal, water and sand, and moves the engine to the turntable and thence across to the house.

25 The engineer makes out a statement on arrival, commonly called a "work report," on which he indicates the condition of the engine and any work which he may know to be necessary. The engine usually receives an independent inspection, however, and notes are made of any work required which has escaped the attention of the engineer. The foreman, or his assistant, distributes the work and is responsible for its performance.

26 Especially at large terminals, engines are frequently stored outside and do not enter the house except for boiler washing or heavy work of some kind. Switch engines, especially those that work night and day, are usually so handled.

27 The organization varies with the requirements, but the engine house and its plant are generally in charge of a foreman who has general supervision over the inside and outside operation. He reports to the master mechanic or general foreman, and attends to locomotive repairs and service including the assignment of enginemen to their runs. He usually has an assistant who attends to the dis-

tribution of work, including the supervision over such foremen of the various classes of work as may be required. Efforts are usually made to keep the night work as low as is consistent with the prompt handling of engines coming in for service or repairs.

28 The cost of service varies greatly at different points. Most roads do the greater part of their work at the more centrally located engine houses and comparatively little at outside points. This naturally causes a considerable difference in the cost of service, but in addition to this, various local conditions, such as the quality of boiler water available, the condition of track, the general condition of the power, and the available help and wage scales, have a considerable effect upon the cost of service. On one road with which the writer is familiar, the cost of service per locomotive varies from 50 cents, or even less, at outside points, to about $3 at one or two important central points where a considerable amount of heavy work is done. The average cost by months for all engines housed during the eight months from July 1909, to February 1910, ranged from $1.50 to $1.73. These figures include service only. The average cost per engine for the eight months is shown in the table.

AVERAGE ITEMIZED COST OF ENGINE HOUSE SERVICE PER MONTH PER ENGINE

PASSENGER ENGINES

Hostling	$0.12
Calling	0.08
Wiping	0.41
Cleaning	0.26
Headlight cleaning	0.07
Boiler washing	0.87
Tank washing	0.11
Flue cleaning	0.10
Inspecting	0.15
Firing-up	0.16
Engine house laborers	0.16
Turning table	0.04
Clinkering	0.24
Supply men	0.12
Coaling engines	0.10
Sanding engines	0.11
Watching engines	0.18

29 The cost of service rendered freight engines on the same road during the year ended June 30, 1909, was 8.4 cents per thousand ton-miles.

AMERICAN LOCOMOTIVE TERMINALS

By William Forsyth, Chicago

Member of the Society

The most interesting example of American engine house practice is that in the classification yards of the Pennsylvania Railroad at East Altoona, Pa. Here the traffic from three divisions of the road is concentrated, classified and despatched. The freight tonnage passing through this terminal is claimed to be the largest handled by any single system of freight yards in the world. The total capacity of the yards is 10,500 cars.

2 The eastbound traffic is composed largely of loaded coal and coke cars, and the number of cars handled per month in this direction is: loaded, 61,308; empty, 1306; total, 62,614. The westbound movement is composed largely of empty cars, with a total of 62,877 cars per month. In 1906 an average of 90 trains per day was received from the Pittsburg division and 60 from the Middle division, and the movement in one direction reached as high as one train every ten minutes for six hours. During the month of November 1909, the engine movement at this engine house was as follows:

Average number of locomotives despatched east and west in 24 hours	243
Maximum number despatched in 24 hours	290
Maximum number despatched in one hour including switch engines	40

3 The trains are operated by consolidation locomotives, and on account of the grades on the eastern slope of the Allegheny mountains westbound trains require three engines, two in front and one as a pusher. Eastbound, the line follows a comparatively light gradient along the Juniata river, and here large trains can be handled by one consolidation engine. There are 35 switch engines, requiring 70 engine crews for day and night operation. During the month of

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November 1905, there were handled over the ashpit a total of 6497 engines. The number of men employed in the yards is 1830. The number of engine men employed during the month averaged 1012 and the number of men employed about the engine house, shops and coal wharf and on the motive power roll was 700.

4 Near the center of the length of the terminal (Fig. 1) is located a large engine house, with ashpits, coal wharf, sand supply, a good-sized machine shop, storehouse and office, with bunk rooms overhead; also a power house, a fan house for heating, an oil house, and a toilet and locker house.

THE ENGINE HOUSE

5 The engine house is in diameter and cross-section the largest structure ever erected for this purpose. It has an exterior diameter of 395 ft. and a turntable of 100 ft. There are 52 stalls 90 ft. deep. The main portion of the house is 65 ft. wide and 30 ft. high. On the outer circle there is a lean-to 25 ft. wide and 18 ft. high. The engines head in toward this lean-to and the smokejack is located alongside the main columns at the outer portion of the main building. The main portion of the house was made 30 ft. high to accommodate a traveling crane, but columns for supporting the crane have not been erected, as jib cranes secured to the main columns were found more desirable. A cross-section of this engine house is shown in Fig. 2.

6 The turntable is operated by an electric motor. There are four drop tables, also operated by electric motors, two of them for driving-wheels, one large table for all wheels except the engine trucks, and another for pony truck wheels.

7 The coal wharf is a large structure arranged with a trestle approach having a grade of 3.88 per cent. The coal is dropped from hopper cars directly into bins and no cover is provided for the cars, as they are emptied entirely by gravity and no men are employed in the unloading. The storage structure is 32 ft. wide and 216 ft. long. A special gate and hood are used for regulating the flow of coal from the pockets to the tender. A steel gate drops below the floor of the pocket and is operated by a compressed-air cylinder.

8 At one end of the coal wharf is a sand house, where sand is dried in large stoves and descends through a grating to a reservoir, from which it is elevated by compressed air to the sand bins overhead, and flows by gravity to the engines.

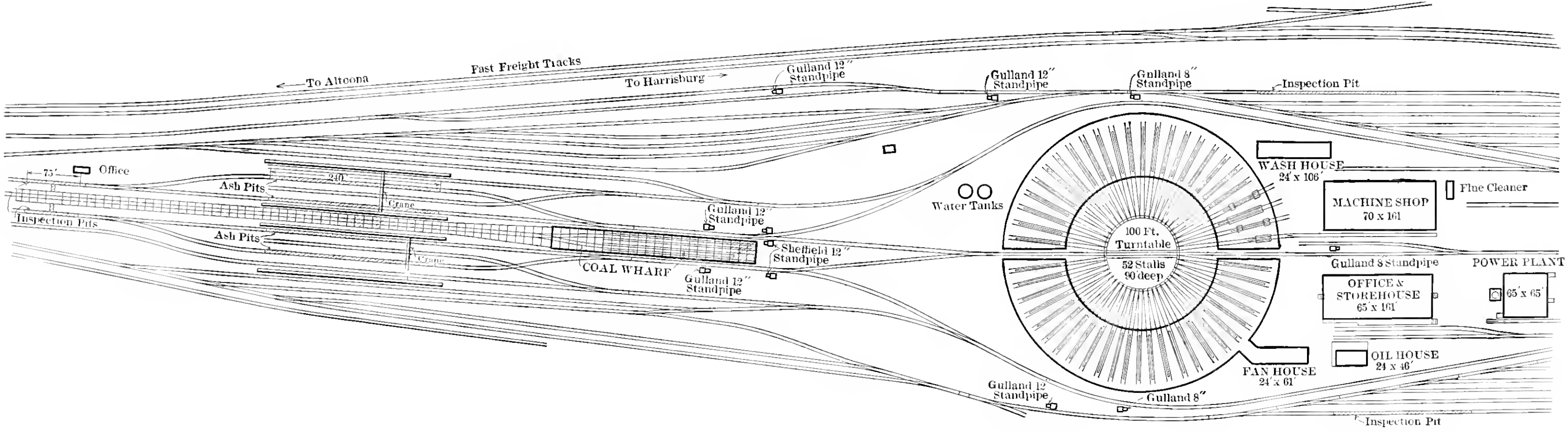

Fig. 1 General Plan of East Altoona Engine House and Auxiliary Structures

9 Near the approach to the coal wharf are four ashpits, each 240 ft. long, two on each side of the wharf incline. Each pair is operated by an overhead 5-ton electric crane which spans four tracks, two of them over the ashpits for ash cars. Ashes are dumped from the engines into steel buckets which run on wheels on a track in the

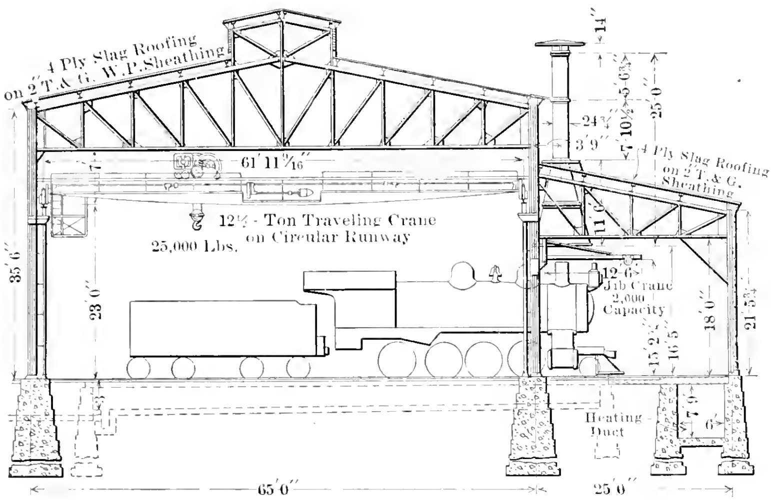

FIG. 2 CROSS-SECTION OF ENGINE HOUSE AT EAST ALTOONA, PA.

ashpit. These buckets are elevated by the crane and transferred to the ash car, where they are dumped. Beyond the ashpits at the extreme end of the coal wharf are inspection pits, 80 ft. long and 3 ft. deep, and connected by an underground passage extending under the coal wharf track.

ENGINE HOUSE ORGANIZATION

10 The work performed in an engine house includes almost everything in connection with locomotive repairs that does not require the locomotive to be sent to the general repair shop. No attempt will be made to itemize these repairs. The work which must invariably be performed periodically consists of boiler testing every six months; boiler washing, from once a week to once a month as necessity arises; staybolt testing each week; examination of smoke-box, draft arrangements and ash pans, each week; testing steam and air gages each month; washing tenders each month;

gaging height of pilots each week; gaging tank water scoops each trip; testing air brakes each trip; draining main reservoirs each week.

MANNER OF REPORTING AND PERFORMING DAILY WORK

11 When a locomotive arrives the first information the organization receives as to work necessary is in the engineer's report which he delivers at the inspection pit when the locomotive is turned over to the inspectors. Five inspectors are here employed, as the work must be done thoroughly in a minimum time, so that the hostler can move the locomotive to the ashpit and make room in the inspection pit for other locomotives waiting. One inspector examines the under-part of the locomotive and tender; one on each side inspects the outside parts, such as driving wheels, rods, steam chests, guides, crossheads and Walschaerts valve gear; there are two air-brake inspectors, one to operate the brake valve and inspect the fittings in cab and air pump, and the other to inspect all other parts of the air and sanding equipment.

12 All defects found by the inspectors are entered upon regular blanks and transmitted, together with the engineer's report, to the gang leader in charge at the inspection pit, who decides whether it is necessary to send the engine to the house or whether the repairs are so slight that they can be made on the outside repair pits in connection with the outbound storage tracks. His decision is marked upon the report, and upon the steam chest of the locomotive, and the reports are forwarded to the work distributor's office by pneumatic tube in 45 seconds. This saving in time over the 10 minutes ordinarily required by messenger is a decided advantage to the work distributor, as he is able to assign the work to various gang leaders, and have the necessary material ordered, before the locomotive arrives in the house or on the engine track.

13 While the inspectors are at work the lamps and torches are filled and trimmed by two lamp fillers. There is no further necessity for the engine house force to open the tool boxes, which are locked bythe engineer, and the keys, together with his time card, delivered to the engine despatcher at the foreman's office. The engineer is then relieved of all responsibility and of the care of the locomotive.

14 The engine moves from the inspection pit to the ashpit, where the firebox, ash pan and smoke box are cleaned. It then moves to

the coal wharf, where the tender is filled with coal; and a little farther on reaches the sand house, where it receives a supply of sand and water. It then moves into the engine house or to the outbound storage tracks, as necessity requires. If it goes to the engine house the track number and the time of arrival are reported by telephone by the turntable motorman to the work distributor, who by this time has the work which was reported by the inspector and engineer subdivided and assigned to various gangs. After completing the work these gangs report the locomotive ready for service to the engine house office, where arrangement is made for the movement of the locomotive to the storage siding to await assignment to a train. If the locomotive does not go to the engine house it is moved directly from the sand house to the storage siding, and the necessary work is assigned to a gang located on the storage tracks to make light repairs, after which the locomotive is reported ready for service.

ENGINE TRACING

15 At East Altoona there are sometimes as many as 200 locomotives within the engine house jurisdiction and it was found necessary to inaugurate some efficient method of locating them exactly at all times, so that men sent to make repairs will have no difficulty in finding any particular locomotive required. This is accomplished by telephone. Each time a locomotive moves to another locality the engine tracer in the foreman's office is advised as to where it came from and where it has been delivered, giving the number, the location on the track and the time in each case. When traffic at East Altoona is normal the engine house must deliver ready for service one locomotive every five minutes during the whole 24 hours of the day, as the engines for three divisions are here concentrated. It is vitally important that everything should run in absolute harmony as any interruption in this rapid flow would quickly result in a congestion on the road.

ENGINE DESPATCHING

16 After the engine tracer has been advised that a locomotive is placed on the storage track for service, he informs the engine despatcher, to whom the crew callers report. The engine despatcher is also in touch with the yardmaster and is the middle man between

the engine house foreman and the yardmaster. As soon as the yard master receives information that he needs a locomotive and crew for a certain train of a given class at a certain time, he advises the despatcher, who immediately calls out a crew, and when they arrive assigns to them the locomotive selected, which is standing on the outbound storage track. A telephone system has been installed whereby all crews may be called. The houses of the engine men have been equipped with telephones connected with the engine house office, an arrangement which dispenses with messengers and enables the crews to be called very promptly.

17 The fireman usually arrives first, and after receiving his time card and keys he takes charge of the locomotive, relieving the engine watcher of any further responsibility, and immediately prepares a fire for road work. The engineer, upon arrival, after receiving his time card at the engine house office and inspecting the bulletin board to read any new orders, goes to the locomotive and oils the machinery, and then waits until he is given the proper signal to move out of the storage yard. The crews are usually called in sufficient time to prepare the locomotive properly for road work prior to leaving the storage track.

ORGANIZATION OF STAFF

18 For the operation of this locomotive terminal an elaborate organization has been worked out, based upon the principle that none but the heads of sub-departments shall report to or receive instructions from the foreman, his assistant or the work distributor. The responsibility of supplying material and the supervision of the workmen are placed directly upon these gang leaders, who are foremen of their respective gangs. Certain questions of discipline must be handled by the foreman personally, but questions relating to rates of pay, transfers, discipline, etc., ought to originate with the gang leaders, and their duties not be confined to giving out work to the men after the distributor has assigned it. This results in successful operation, but it also gives some dignity to the position of gang leader, and at the same time relieves the foreman of petty details.

19 The foreman of a large engine house should not be an ordinary shop man, but should have some outlook over and interest in the operating department. He should be a good disciplinarian, commanding the respect of his men, should display clear judgment and

form conclusions quickly. He should be a good all-round organizer and capable of taking care of business promptly during rush hours. He should know how to make brief and intelligent reports and possess mechanical ability. He should be broad-minded enough to recognize that there is a commercial side to transportation, and should not be overburdened with office work. His assistants should possess sufficient ability to decide what work may be slighted or not done at all, and a locomotive still be safe to make one or more round trips.

20 The engine house foreman receives from the division master mechanic instructions pertaining to such matters as the number of men required, rates of pay, discipline, maintenance of his entire plant, and standards. He receives from the division superintendent instructions relating to crews and despatching of locomotives, and carries out such discipline of the engine crews as may be imposed by the division superintendent through the road foreman of engines. He must coöperate with the road foreman of engines concerning the condition of power and its performance on the road, and the amount of coal and oil consumed. He must carry out orders issued by the road foreman of engines concerning the assignment of locomotives and crews. At East Altoona the engine house operation is a continuous one throughout the day and night, and the night force is practically the same as the day force.

21 Reporting directly to the engine house foreman are the *assistant day foreman and assistant night foreman*. Reporting to assistant foremen for office work are the *first clerk*, who takes all the foreman's and the assistant foremen's dictation, and the *second clerk*, who has charge of all messengers and ordinary clerks who may be engaged in computing the time and earnings of the men and in getting together all the information required by the master mechanic's shop clerk and for properly keeping the records. Next in order is the *engine despatcher*, to whom report the *engine tracer*, the *callers* and the *clerks* who keep the records of engineers and firemen and of locomotives arriving and departing. The engine despatcher marks up the crew board, issues time cards to engine crews going out, and accepts and approves them upon their return.

22 Next in order reporting to the assistant foreman are the various *gang leaders*. First is the gang leader in charge of the machine shop. The work of his men is confined to machine and vise work, and they are not called upon to leave the machine shop and make repairs in the locomotive shop or storage yard except in cases of emergency. Their work is chiefly preparing and fitting the repair parts which

the engine house employees apply to the locomotives. The gang leader in charge of the blacksmith shop has charge of all smiths and helpers, as well as the forces of flue welders and laborers in the engine house engaged in piecing flues and preparing them for locomotive boilers. The gang leader of the power plant has full charge of stationary engineers and firemen, electricians and wiremen. Another gang leader has charge of the ordinary helpers and sweepers in the engine house, who keep the shop property clean.

23 The foreman in charge of all employees actually handling locomotives, from the time they arrive at the terminal until they are turned out, also of all workmen engaged in the engine house or storage yard, is called the *work distributor.* Clerks reporting to his two *assistants* receive the engineers' and inspectors' work reports and copy the work required on slips of paper numbered consecutively and properly dated. These slips are then delivered to the gang leaders of the men who perform the work.

24 The men composing the gangs working on a piece work basis are divided into pools of three or four men, with leaders. The *pool leaders* are under the direction of gang leaders. When the earnings of three or four workmen are pooled it is found that each man is determined that the others should perform their fair share of work, and in case one man fails to do this the remainder insist that the lazy or careless workman be taken out of their pool.

25 The gang leaders at the inspection pits are in charge of *inspectors, lamp fitters and engine preparers,* who handle the locomotives between the inspection and ashpits.

26 There are three *assistant gang leaders* in charge of the *engine preparers.* Assistant No. 1 has charge of all work in cleaning fires and placing the locomotives in the engine house or storage yard and of *the ashpit men and crane operators* who load cinders. Assistant No. 2 has charge of the *coal gagers and sand house men, turntable operators* and men engaged in handling locomotives from the engine house to the storage yard. Assistant No. 3 has charge of the men handling locomotives in the storage yard and despatching them when ordered for service, including *engine watchers, switchmen and engine timers.*

27 Next reporting to the work distributor is the *gang leader of boiler washers,* whose men wash out the tenders, blow out, wash, fill and fire all boilers, and watch locomotives until they are removed from the engine house. Next is the *gang leader of staybolt inspectors,* whose men test staybolts and examine fireboxes and tubes. There

is a *gang leader of boiler makers*, engaged in renewing tubes and staybolts, patching, testing and calking tubes, and general boiler work. A *gang leader of engine cleaners* has charge of men cleaning locomotives and tenders. There is a regular schedule for doing this work, and it is so arranged that the work is performed when the locomotives are receiving staybolt repairs or boiler washing. A *gang leader of spongers* is in charge of packing journal boxes and other work relating to lubrication. In the engine house there is a *gang leader of machinists*, who are engaged in setting valves, renewing packing and all other general machinist work on the locomotive proper. The *gang leader of tank repairs* is in charge of repairs to tenders, frames, tanks and couplers, of renewing truck wheels, and other tender repairs. The *gang leader of air-brake repair men* keeps in order the air brakes and sanding equipment.

28 The gang leaders of men on piece work should have not more than ten or twelve men under them, with the exception of the gang on boiler work, which may require from one to four days to complete.

POOLING LOCOMOTIVES

29 Improved engine house facilities, more system and better organization are favorable to the pooling of locomotives, and this practice has become more general for freight engines in the United States. As recently as in 1905 the reports on pooling presented at the International Railway Congress indicated that pooling was not used on the majority of railways in the United States under normal conditions of traffic. The large increase in traffic in proportion to the number of locomotives in 1906 and subsequent years has compelled most of the roads to resort to the pooling of freight engines and the double-crewing of passenger engines, and these methods are now well established on the majority of American railways. By improved methods the operations of cooling down, washing, and filling with hot water may be performed in less than two hours without injury to firebox and tubes, and this alone has contributed in a large measure to the success of pooling. The reduction in boiler pressure from 225 lb. to 160 and 180 lb. has also reduced the number of boiler failures and permitted the more continuous use of locomotives which results from the pooling system.

30 The amount of work which the engineers and firemen do at the engine houses is now so small that it is almost confined to lubrication of machinery and inspection of tools and supplies on engines,

and no dependence is placed on them for repair work. The engineer is required to report any defects or needed repairs which he observes while running the locomotive or by casual inspection on the outside. The machinery underneath is inspected by men regularly employed for that purpose, and inspection pits in the tracks approaching the engine house are now regarded as an essential of a modern locomotive terminal. With the changes in practice above indicated, the pooling of freight engines is rendered more successful and satisfactory and its effect on the cost of locomotive repairs is not so pronounced as formerly.

31 On some railways where shop facilities are limited, locomotives are required to make a large mileage before they go in for general repairs. The principal items which send engines frequently to the shop are worn tires, defective tubes, and, perhaps, worn driving boxes. At some engine houses all these repairs are made, the worn tires being replaced by new ones or by others which have been turned at the shop. In this way such machinery as rods, crossheads, guides and link motion, is kept in service, so that passenger locomotives make as high as 127,000 miles, and freight locomotives, 100,000 miles between general repairs, one passenger locomotive making 256,000 miles between shoppings. Passenger locomotives average 120,000 miles and freight locomotives, 95,000 miles.

32 On the Chicago, Burlington & Quincy for the last six months of 1909, pooled freight engines made on one division as high as 4167 miles per month and 110 engines on three divisions averaged 3777 miles per month. On other roads passenger engines double-crewed make an average of 6500 to 7500 miles per month, one road reporting for engines in express service 418 miles per day and 12,780 miles per month.

HANDLING ENGINES

By H. H. Vaughan, Montreal, Can.

Member of the Society

The desirability of pooling engines in place of operating them by regularly assigned crews depends, in the writer's opinion, on whether the engines are engaged in passenger or freight service, and in the latter case, on the conditions which exist.

PASSENGER SERVICE

2 Where traffic conditions admit of the engine making greater mileage than can properly be run by one crew, two crews assigned to one engine, or three crews to two engines, will enable the engine to make as great a mileage as is desirable. On account of the comparatively short time occupied from terminal to terminal, the crews can usually make a round trip without holding the engine longer than is required to handle it and prepare it for the return trip or to await its train. By using more than one crew to the engine, it is theoretically available on its return just as soon as though it were pooled. In practice, unless pooling is carried to the extent of sending out any engine on any train, certain engines are regularly used on certain trains or groups of trains, and it is comparatively easy to arrange the crews and engines so that a reasonable time may be allowed for repairs and yet ample service be obtained from the engine. When working with assigned crews it is of course usual to employ some extra passenger men to take the place of the regular men, who are also available in case an extra trip is required from an engine on account of specials or extra sections of regular trains. Where regular scheduled trains have to be provided for, this system is as flexible and convenient

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as pooling and has the additional advantage in passenger service that the men run certain trains regularly, and will consequently give better service than when handling a number of trains indiscriminately.

3 Pooling in passenger service probably does not require much discussion. The system is not in extensive use and will presumably have few advocates. The writer would, however, state as a result of his experience with both pooled and assigned engines in passenger service, that he is most strongly opposed to pooling in this service and considers that far better results can be obtained from assigned crews.

FREIGHT SERVICE

4 Here conditions are very different. The time is slow and a long time is occupied from terminal to terminal, so that crews may require a full allowance of rest on arrival, or may even have to be relieved on the road. Few, if any, of the trains run at regular hours, and in place of following a defined schedule, the demand for engines varies with the traffic. When business is heavy, engines are wanted as soon as they are repaired and ready for service, making it difficult, if not impossible, to select the engines in any particular order. By pooling, such difficulties may be more easily met, especially at large terminals. When engines are assigned the practice usually required by the agreement with the men is that engines shall be prepared and despatched in the order in which they arrive, but if the engine is ready its use may be retarded by the time required by the crew for rest. In pooling, both these objectionable conditions vanish. An engine may be turned at once if fit for service and thus rendered immediately available, and the movement of the men being entirely independent of that of the engines, the detention of engines at a terminal can be regulated by simply increasing or decreasing the number in the pool.

5 Under such conditions, if pooling is not carried on in name, it will be in fact, simply because business can not be handled unless engines are used without reference to the order of their arrival. Granted therefore that pooling is advantageous under these conditions, it should be done properly. All the features necessary to a successful pooling system must be employed, such as thorough terminal inspection independent of the engine crews, and arrangements for handling tools and engine supplies, and caring for headlights, oil cups, etc. If pooling is resorted to when business is especially heavy, or

when traffic is disturbed by storms or by other causes, without proper arrangements being made, the results are most objectionable. Under these circumstances, the condition of the power will depreciate rapidly and the service rendered will be exceedingly inefficient. The maxim is frequently stated, "If you pool, pool," and its wisdom has been demonstrated by experience. The real question about pooling is therefore whether there are conditions under which it is preferable to adopt the alternative practice, that of running engines with assigned crews. This depends on the results obtained from the two systems, which are in the writer's experience as follows:

6 *Mileage.* It is possible to obtain somewhat greater average mileage per engine under the pooling system, but the increase does not exceed ten per cent when traffic is being handled smoothly and without excessive congestion and delays.

7 *Repairs.* When running successfully under the assigned engine system, repairs are less than when similar conditions exist with pooled engines. A man running an engine regularly keeps up the smaller details and knows what work is required at once, and what must be looked after in due time. His inspection reports are more reliable than those of a man who has had an engine for one trip only. As he has to run the engine next trip as well, he will handle it with greater care and avoid any action that will cause him trouble in the future. Men who have been accustomed to running pooled engines will not do all this at once, but they most certainly will if assigned to an engine for any length of time, and the difference is noticeable in engine houses where some engines are assigned and some are pooled.

8 Engines are sometimes taken care of by the headquarter station system, the work required to maintain the engine in proper condition being done at the terminal designated as the home station, while at the other terminal the only work done is that necessary for the return trip. With this arrangement, even with pooled engines, the same crew will, if possible, make the round trip; but when they are changed, practically as much work is required at the away station as at the home station. The result is a considerable increase in the cost of repairs, for there is not as a rule very much difference in the cost at the home station.

9 When the assigned engine system proves inadequate for traffic demands, the results change. Men will endeavor to book enough work against the engine to hold it until they have rested, and on the other hand engines are liable to be wanted before repairs that are actually required are completed. Under these conditions engines may be bet-

ter and more cheaply maintained when pooled; but under normal conditions the writer's experience would show that with assigned crews the cost of running repairs may be reduced five to ten per cent and better mileage obtained from the engines between shoppings.

10 *Fuel.* It is almost impossible to determine the fuel consumed by an engine on an individual trip, and consequently difficult when pooling to keep any record of the amount of coal used by different men. A record may be kept by engines, but it is then impossible to locate the responsibility for any excessive consumption. The practical result is that on pooled engines, individual fuel records are of comparatively little use. With assigned engines, while trip records may not be individually accurate, the average of several consecutive trips soon becomes so, as the variation of the amount of coal left on the tender, while important on one, is of comparatively small importance on a number of trips. There is no doubt in the writer's mind that individual coal records, whether by trip or by period, are an important factor in obtaining economical results in fuel consumption, both from men and from engines, and he ascribes the good results that have been obtained on the Canadian Pacific Railway largely to the careful way in which the records have been watched.

11 Apart from the records, the familiarity of the men with the engines has an important bearing on fuel consumption. Most engines vary slightly in the way they burn the coal, in the nature and intensity of the draft, and in the best position for the throttle and reversing lever. Crews knowing an engine thoroughly learn about these peculiarities, while they do not when running a different engine each trip. One crew will obtain from an engine results that are impossible for another crew, and thus the result with assigned crews is a tendency to higher efficiency than when every engine has to be drafted and adapted to do the work with the poorest crew on the division. It is only necessary to watch the difference in the way an engine is handled by a regular crew and by a pooled crew, to realize the advantage of the former, and important results have been clearly shown with the same men and engines, on divisions where the two systems have been in effect.

12 *Service.* The remarks that have been made in connection with repairs and fuel apply with almost equal force to the class of service obtained from the engines, with reference to failures, breakdowns and ability to make the time required. A crew that knows the engine will get more out of it than one that does not. They will notice any difference in its working and will take more interest in getting

any defect rectified. They will keep their equipment in better condition and will pay more attention to bearings which show signs of heating, etc. All these conditions lead to better and more efficient service.

13 *Engine House Expenses.* Inspection, the care of tools, the filling of lubricators, headlights and cab lamps, are commonly looked after on assigned engines by the crews. When engines are pooled this work has to be done by the engine house force. At a large terminal this expense is not large, but when the number of engines handled is small, it is difficult to arrange the duties of the men doing this work to prevent its becoming a serious item. Conditions vary on different roads in this respect, but the fact remains that this work is not in any way burdensome to men having a regular engine, while it is burdensome if they are required to prepare a different engine each trip, and consequently they object to it very strongly. In the majority of cases this work constitutes an additional charge on engines that are pooled.

CONCLUSION

14 In conclusion, the writer considers that in passenger service pooling is objectionable under any conditions and should be avoided if possible.

15 In freight service, pooling is advisable if conditions are such that engines cannot be run with assigned crews, and probably on divisions where business is so heavy that sixty engines per day or over are despatched from the terminal; but the writer's experience is that where assigned crews can be used on engines, the cost of repairs, the amount of fuel consumed, and the class of service obtained, will all be more satisfactory.

16 He therefore regards pooling as a practice that may be necessary under certain conditions, but that is certainly not desirable if the alternative system can be satisfactorily carried out.

A REGENERATOR CYCLE FOR GAS ENGINES USING SUB-ADIABATIC EXPANSION

By Prof. A. J. Frith, Chicago

Member of the Society

Some confusion has arisen in thermodynamic problems from the tendency of many older writers to assume ideal conditions and carefully work out problems to their legitimate conclusions without regard for the losses that inevitably exist in a practical installation. While it may be difficult to determine the extent of their influence, it will clarify the conclusions if such losses are pointed out even approximately, and help dispel the popular belief that theory and practice are incompatible in the internal combustion engine.

2 An ever new and interesting problem is that of how far, commercially, economy of fuel can be carried in the gas engine. In the direct-expansion engine it has been proved theoretically and practically that an increase of compression reduces the fuel consumption, and this precompression has in some instances reached a commercial maximum. High pressures, however, entail heavy flywheels and finely finished valves and joints, require operators of greater ability and otherwise tend to increased expense of maintenance, all of which it would be commercially desirable to eliminate. But how can it be done?

3 Thermodynamics has shown that there is theoretically another method of operating prime movers: namely, on regenerative cycles. These cycles which are later described in this paper, have a theoretical economy as high as the Carnot cycle, the ideal cycle of expansion engines; and for gas engines have the great advantage of a high mean effective pressure, when the Carnot cycle is attenuated and weak.

4 Engines operating on regenerator cycles, however, have not come into use, despite numerous patented designs, which would lead

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us to suspect that from a practical standpoint there is a fallacy in them, though there is no hint of it in the theory founded on ideal conditions.

5 It appears curious that the principle of regeneration, so highly successful in metallurgical and gas-burning installations, which is present in its essence in every boiler plant and in most cases of the transfer of heat and is absolutely essential in hot air engines, noted for their ease of operation, is described as inapplicable to the internal combustion engine.

6 What is the reason for this reversal of judgment in the case of the internal combustion engine? Investigations show that under actual operative conditions the engine cylinder must be water-cooled and that the contact of cool surfaces with incandescent gases withdraws a large percentage of the heat developed by the fuel. Thus, in a test quoted by H. A. Golding, a heat balance shows that

The heat to water cooling = 39.4 %
The heat to exhaust = 37.8 %
The heat to i.h.p. = 22.8 %

or that this loss of water cooling amounts to nearly 200 % of the power developed.

7 Whatever other conditions control this source of waste, we can consider it to vary as the difference between the average temperature of the burning charge and the temperature of the cooler walls. In this particular test the temperature of the charge may have been as high as 2800 deg. fahr. at the peak of explosion and 1500 deg. at the point of release, or an average temperature in the neighborhood of 2150 deg. With water cooling, even as high as 200 deg., there would be a difference of 1950 deg., causing a water loss of 40 %.

8 Now regenerator cycles all depend upon the passing of the gases through the regenerator during the exhaust and to make them most effective the temperature must be kept as high as possible to the very end. For example, if the temperature were 2800 deg. both at the commencement and end of the stroke, giving an average temperature of 2800 deg. and a difference of 2600 deg. with 200 deg. water cooling, there would be a water loss of, roughly,

$$\frac{2600}{1950} \times 40 = 50\ \%$$

chargeable to all the heat in the cycle. Part of the heat is regenerated, however, so that all the loss must fall on the balance; that is, be supplied by combustion. This raises the loss to 56 % and while

correct theory may show the exhaust loss to be only say, 22 %, the heat balance for the regenerator cycle becomes, practically, as follows:

Heat to water loss	= 56 %
Heat to exhaust	= 22 %
Heat to i.h.p.	= 22 %

9 Thus we see that the high constant temperature of expansion in the older regenerator cycles causes an excessive loss of heat to the water-cooled surfaces, and is in itself sufficient to account for the failure to realize in practice the degree of economy expected. This seems to have been unrecognized by designers, who not only fail to provide means for mitigating this evil, but as is most frequent in patented designs, favor burning the gases to volumes greater than that of the original charge, in the largest cylinders possible. By this means the loss to the water-cooled surfaces is increased and it

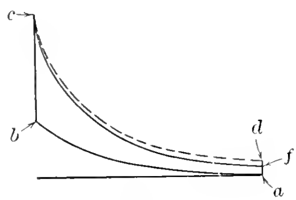


FIG. 1

THEORETICAL GAS ENGINE CYCLE

is not surprising that poor results followed their efforts. In spite of this every regenerator cycle within our knowledge includes constant temperature compression and expansion.

10 There are some other defects of the regenerator itself; thus, if its efficiency is to be very high it must be bulky, with large clearance, though this trouble practically disappears when the efficiency is moderately high, but successful results depend upon delivering an exhaust of comparatively low temperature, and as the regenerator is the only means provided for that purpose in this cycle, moderate regenerator effect is for our purpose inoperative.

REGENERATOR CYCLE WITH SUB-ADIABATIC EXPANSION

11 Attention is now directed to a new regenerator cycle with *sub-adiabatic expansion* which avoids the defects mentioned and which theoretically and practically promises unusual results. If, in Fig. 1, we have a card similar to an ordinary gas engine card, we recog-

nize the compression *ab*, the explosion *bc*, the expansion *cd* and the exhaust *da*. We know that the efficiency of this cycle, afterwards modified by the degree of water loss, equals the heat supplied during *bc*, less the heat rejected during *da*, divided by the heat supplied during *bc*.

$$\text{Eff.} = \frac{H - exhaust}{H} = \frac{area}{H}$$

Roughly, the degree of water loss depends on the average temperature during expansion. In previous regenerator cycles it has been from the *exhaust gases* that heat has been extracted by the regenerator. What happens if it is from the expanding gases that the regenerator absorbs its heat?

12 If, in brief, during the expansion *cd*, the burning gases pass through the regenerator, and are cooled thereby, evidently the pressure will fall more rapidly than by free expansion, say according to a line *cf* *steeper* than the adiabatic line, and the heat rejected by the exhaust *fa* is evidently less than the exhaust *da*, while if this heat abstracted by the regenerator is added to the explosion line *bc*, less heat is thereby required by burning to reach the pressure *c*. Let $F = \%$ of heat regenerated; then the heat supplied by burning $= (1-F)\ bc$ and

$$\text{Eff.} = \frac{\text{area of the card in B.t.u.}}{(1 - F)\ H}$$

which becomes larger as F increases to its higher values.

13 As the degree of regeneration increases, the point *f* must approach *a*, the pressure, volume and temperature of the original charge, where no heat would be rejected in the exhaust and the efficiency would be a maximum. It is also noticed that the *average* temperature of expansion *cf* lying below the line of free expansion is less than that of the regular card and far less than that of the constant temperature expansion of the other regenerative cycles. Hence, the per cent of heat loss by water-cooling, in what I have called the Frith Sub-Adiabatic Regenerative Cycle, should be lower for all the heat present than by the method mentioned, and when charged to heat developed by burning is still less than that charged to ordinary cycles.

14 The method by which the per cent of heat loss through cooling is determined may form the subject of another communication when checked with a number of engine tests. The calculations indicate, however, after checking the results with the inferences drawn from

tests of boilers by the United States Geological Survey, that the per cent of heat loss is not directly proportional to the number of square feet of surface. Similar methods show that the regenerative effect may be expressed in per cent of heat or temperature available; that is, in per cent of the difference between the temperature of the cooler gases passing into the regenerator and that of the hotter gases returning through the regenerator. This percentage again does not directly depend upon the amount of surface.

15 To recapitulate, the regenerator cycle hitherto known (Fig. 2) is an ideally perfect cycle, but besides requiring a 100 per cent regenerator, the cycle under practical conditions entails an excessive loss of heat by water cooling, and its line of expansion at constant temperature is flatter than that of free expansion and represents *expansion with the addition of heat.*

16 The regular gas engine cycle (Fig. 3), ideally treated, has an expansion line coincident with that of free expansion, entails ordinary

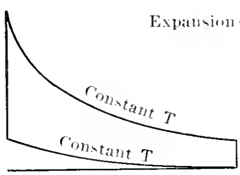


Fig. 2

Constant Temperature Cycle

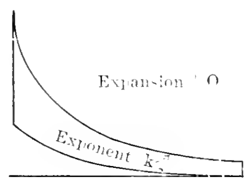


Fig. 3

Adiabatic Cycle

loss of heat to water-cooling, and represents *free expansion without addition or subtraction of heat.*

17 The regenerative sub-adiabatic cycle, Fig. 4, requires, even for its maximum efficiency, regenerators of only practical efficiency. Its line of expansion, steeper than the line of free expansion, entails ordinary, if not less, loss of heat to water cooling and represents *free expansion with the subtraction* of heat.

18 The discussion of this line of expansion seems not to have been treated by writers on thermodynamics and if this is so it is a new cycle of operation. A comparative estimate of the various cycles with moderate compression and a mechanical efficiency of 80 per cent, including the Diesel oil engine, is as follows:

ESTIMATED HEAT BALANCE OF VARIOUS CYCLES

Type	Compression Absolute	Water Cooling Per cent	Exhaust Per cent	I.h.p. Per cent	Mech. Eff. Per cent	Brake Eff. Per cent
Regenerative cycle; expansion $+H$		56	22	22	80	17.6
Diesel engine......................	515	35	28	37	76	28
Regular gas engine; expansion $+O$..................	140	35	38	27	80	22
Sub-adiabatic regenerative cycle 65% regenerator; expansion $-H$	140	30	25	45	75	34

19 We now desire to obtain a rational expression for the efficiency to be expected in a sub-adiabatic regenerator cycle, treating it as for air. It is evident that it depends not only on the compression, but also on the degree of regeneration used, remembering that for any point as P_1, Fig. 5, the heat in 1 lb. of mixture equals the area under the line of adiabatic expansion, with the exponent k, if it be carried to the line of no pressure.

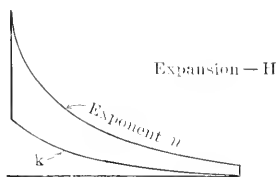


FIG. 4

FRITH SUB-ADIABATIC REGENERATIVE CYCLE

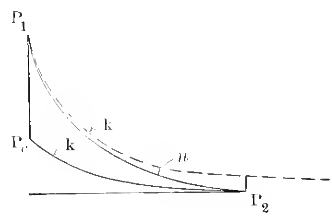


FIG. 5

FRITH SUB-ADIABATIC REGENERATIVE CYCLE OF MAXIMUM EFFICIENCY

20 The same is true for the point P_c. The difference in area between these two lines of complete expansion equals the heat furnished per pound, while the difference between the two lines at P_2 equals the heat rejected. Fig. 5 shows the condition of maximum economy, or no rejection of heat, and the line of expansion with an exponent n, steeper than free expansion, shows the effect of the heat withdrawn by the regenerator. The heat present at P_1 = heat regenerated + the heat represented by area under line n + the heat represented by area under line from P_2, exponent k. The heat-contents at any point as $P_1 = \frac{p_1 V_1}{k-1}$. If the charge be compressed adiabatically from P_2 to P_c, heat be added, partly by the regenerator, from P_c to P_1, expansion be from P_1 to P_2 with abstraction of heat by

the regenerator, it is steeper with its exponent n than free expansion, and the heat abstracted by a regenerator equals the heat given out when conditions are normal.

21 Let F = the per cent of heat available that is regenerated and $F^{\text{max.}}$ = maximum regenerator per cent available. Then,

$$\text{Heat added to the cycle per pound} = \frac{p_1 V_1}{k-1} - \frac{p_c V_1}{k-1}$$

$$\text{Heat added by the regenerator} = F\left(\frac{p_1 V_1}{k-1} - \frac{p_c V_1}{k-1}\right)$$

$$\text{Heat abstracted by the regenerator} = F\left(\frac{p_1 V_1}{k-1} - \frac{p_c V_1}{k-1}\right)$$

$$\text{Heat added by combustion} = (1 - \text{F})\left(\frac{p_1 V_1}{k-1} - \frac{p_c V_1}{k-1}\right)$$

$$\text{Heat under the curve} = \frac{p_1 V_1}{n-1}\left[1 - \left(\frac{V_1}{V_2}\right)^{n-1}\right]$$

$$\frac{p_1 V_1}{k-1} = F^{\text{max.}}\left(\frac{p_1 V_1}{k-1} - \frac{p_c V_1}{k-1}\right) + \frac{p_1 V_1}{n-1}\left[1 - \left(\frac{V_1}{V_2}\right)^{n-1}\right] + \frac{p_2 V_2}{k-1}$$

Dividing by $\dfrac{p_1 V_1}{k-1}$

$$1 = F^{\text{max.}}\left(1 - \frac{p_c}{p_1}\right) + \frac{k-1}{n-1}\left[1 - \left(\frac{V_1}{V_2}\right)^{n-1}\right] + \frac{p_2}{p_1} \times \frac{V_2}{V_1}$$

from which

$$F^{\text{max.}} = \frac{1 - \dfrac{k-1}{n-1}\left[1 - \left(\dfrac{V_1}{V_2}\right)^{n-1}\right] - \dfrac{p_2}{p_1} \times \dfrac{V_2}{V_1}}{\left(1 - \dfrac{p_c}{p_1}\right)} \quad \ldots .(1)$$

an expression for $F^{\text{max.}}$ when pressures of any particular case are given, for the value of k = 1.405 and

$$n = \frac{\text{Log } P_1 - \text{Log } P_2}{\text{Log } V_2 - \text{Log } V_1} \text{ (a well-known expression)} \ldots\ldots(2)$$

Also

$$(1 - F^{\text{max.}})\left[1 - \left(\frac{p_c}{p_1}\right)\right.$$

$$= \left\{ 1 - \frac{1 - \frac{k-1}{n-1}\left[1 - \left(\frac{V_1}{V_2}\right)^{n-1}\right] - \frac{p_2}{p_1} \times \frac{V_2}{V_1}}{1 - \left(\frac{p_c}{p_1}\right)} \right\} \left[1 - \left(\frac{p_c}{p_1}\right) \right]$$

Reducing to

$$(1 - F^{\text{max.}})\left[1 - \left(\frac{p_c}{p_1}\right)\right] = -\frac{p_c}{p_1} + \frac{k-1}{n-1}\left[1 - \left(\frac{V_1}{V_2}\right)^{n-1}\right] + \frac{p_c}{p_1}\left(\frac{V_1}{V_2}\right)^{k-1}$$

Since $p_2 V_2^k = p_c V_1^k$ or $p_2 V_2 = p_c V_1 \left(\frac{V_1}{V_2}\right)^{k-1}$

and as

$$-\left(\frac{p_c}{p_1}\right) + \frac{p_c}{p_1}\left(\frac{V_1}{V_2}\right)^{k-1} = -\frac{p_c}{p_1}\left[1 - \left(\frac{V_1}{V_2}\right)^{k-1}\right]$$

we have

$$(1 - F^{\text{max.}})\left[1 - \left(\frac{p_c}{p_1}\right)\right] = \frac{k-1}{n-1}\left[1 - \left(\frac{V_1}{V_2}\right)^{n-1}\right] - \frac{p_c}{p_1}\left[1 - \left(\frac{V_1}{V_2}\right)^{k-1}\right] \qquad (3)$$

Now the efficiency $= \dfrac{\text{work}}{\text{heat supplied by combustion}}$. Therefore

$$\text{Eff.}^{\text{Max.}} = \frac{\frac{p_1 V_1}{n-1}\left[1 - \left(\frac{V_1}{V_2}\right)^{n-1}\right] - \frac{p_c V_1}{k-1}\left[1 - \left(\frac{V_1}{V_2}\right)^{k-1}\right]}{(1 - F^{\text{max.}})\left(\frac{p_1 V_1}{k-1} - \frac{p_c V_1}{k-1}\right)}$$

Dividing by $\frac{p_1 V_1}{k-1}$ and substituting the values from Equation 3 we have

$$\text{Eff.}^{\text{Max.}} = \frac{\frac{k-1}{n-1}\left[1 - \left(\frac{V_1}{V_2}\right)^{n-1}\right] - \frac{p_c}{p_1}\left[1 - \left(\frac{V_1}{V_2}\right)^{k-1}\right]}{(1 - F^{\text{max.}})\left(1 - \frac{p_c}{p_1}\right)} = 1, \text{ or } 100\% \quad (4)$$

a result that is startling, when we realize that we have been taught

that the expression for efficiency $\left(\frac{T_1 - T}{T_1}\right)$, however high, can never reach unity with the condition of our problem, that if the expansion with the abstraction of heat can reach the pressure and volume of the original charge at p_2, the temperature must be that of the entering charge, then there is no loss of heat to the exhaust, and as there is no isothermal compression with its loss of heat, all the heat of combustion must be changed into work, and 100 per cent efficiency is the necessary result.

22 The expression (Equation 1) for the value of F $^{max.}$ has been worked out for several conditions of practical compression and pres-

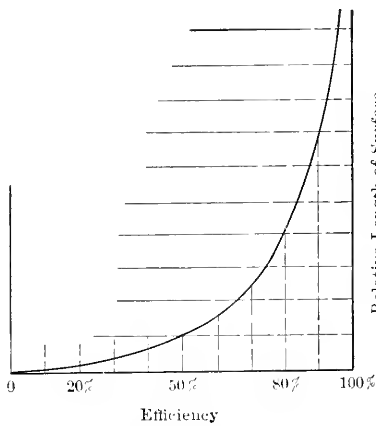


FIG. 6. VARIATION OF REGENERATOR EFFICIENCY WITH SIZE

sures and gives values between 72 per cent and 82 per cent for regenerator efficiencies, and we know that many regenerators are in use where these figures are exceeded. It may here be of interest to examine Fig. 6, which represents the variation of the efficiency of a regenerator with an element of its size.

23 The abscissæ in Fig. 6 represent efficiency, the ordinates length, and the diagram shows that the efficiencies increase very rapidly with the lower values, but the curve finally is an asymptote to the length, explaining the bulk of very high efficiency regenerators, while practical dimensions possibly reach their limit at the crest of the curve, at about 75 per cent, which is in favor of high cycle efficiency with practical construction.

24 We know that the lowest temperature of the regenerator itself must be higher than the temperature T_c, pertaining to P_c, Fig. 5,

and the returning gases issue therefrom at a still higher temperature. How, then, can the lower temperature of atmospheric exhaust be possible?

25 Remember that we use two cylinders, freely open to each other through a regenerator, and that Fig. 5 represents the change of volumes and pressures, for the whole charge, partly in one, and partly in the other cylinder. The pressures in each, at the same moment, must be equal; but the temperatures are not equal, one being that of the gases before they pass through the regenerator, and the other that of the gases after they issue therefrom. The pressures in Fig. 5 result from the combined temperatures of the entire charge volume. Remembering that the gases are returned through the regenerator progressively throughout the stroke, let us consider a small volume of gas that issues from the regenerator, early in the cycle. It is at a temperature due to the regenerator, and is lower than the average, indicated by Fig. 5, but it is at the pressure shown. If we consider this particle as expanding freely to atmospheric pressure, its individual temperature will be very low at exhaust. The contrary effect follows with a particle issuing at the end of the cycle. The actual temperature of exhaust is the combined effect of all the particles, each chilled to a different degree by its own rate of expansion after it has left the regenerator. Hence it is a fact that a portion of the gases repassing through the regenerator, at the high pressure of the early part of the cycle, are themselves at a lower temperature than the average temperature corresponding to that pressure. They are expanded from this high pressure to atmospheric pressure, after they have left the regenerator, and hence reach refrigerating temperatures, and temper the additions at lower pressures, in the final temperatures. This expansion being governed by two exponents n and k gives expression not easily reduced, but a plain summation of an example will be given later on that results in a final figure at an approximately reasonable temperature.

26 Where the regenerator has an efficiency F less than $F^{\text{max.}}$, as may be commercially desirable, it is evident that the work under the curve of expansion is less than for the exponent k, and greater than for n of maximum efficiency. Let us assume that this reduction of work is proportional to $\dfrac{F}{F^{\text{ max.}}}$ times that occasioned by maximum efficiency, which may then be expressed by

$$\frac{F}{F^{\text{max.}}}\left\{\frac{p_1 V_1}{k-1}\left[1-\left(\frac{V_1}{V_2}\right)^{k-1}\right]-\frac{p_1 V_1}{n-1}\left[1-\left(\frac{V_1}{V_2}\right)^{n-1}\right]\right\}$$

and having determined $F^{\text{max.}}$ and n (Equations 1 and 2), and p_1v_1, p_2v_2, p_c, and the value to be used for F, the efficiency may be expressed as

$$\text{Eff.} = \frac{\text{work under curve } k - \text{decrease of work} - \text{work under } P_c\ P_2}{\text{beat furnished by combustion}}$$

or

$$\text{Eff.} = \frac{\left\{ \begin{array}{l} \dfrac{p_1 V_1}{k-1}\left[1 - \left(\dfrac{V_1}{V_2}\right)^{k-1}\right] \\ -\dfrac{F}{F^{\text{max.}}}\left\{\dfrac{p_1 V_1}{k-1}\left[1 - \left(\dfrac{V_1}{V_2}\right)^{k-1}\right] - \dfrac{p_1 V_1}{n-1}\left[1 - \left(\dfrac{V_1}{V_2}\right)^{n-1}\right]\right\} \\ -\dfrac{p_c V_1}{k-1}\left[1 - \left(\dfrac{V_1}{V_2}\right)^{k-1}\right] \end{array} \right\}}{\left(1 - F\right)\left(\dfrac{p_1 V_1}{k-1} - \dfrac{p_c V_1}{k-1}\right)}$$

Dividing by $\dfrac{p_1 V_1}{k-1}$ we obtain

$$\text{Eff.} = \frac{\left\{ \begin{array}{l} \left[1 - \left(\dfrac{V_1}{V_2}\right)^{k-1}\right] \\ -\dfrac{F}{F^{\text{max.}}}\left\{\left[1 - \left(\dfrac{V_1}{V_2}\right)^{k-1}\right] - \dfrac{k-1}{n-1}\left[1 - \left(\dfrac{V_1}{V_2}\right)^{n-1}\right]\right\} \\ -\dfrac{p_c}{p_1}\left[1 - \left(\dfrac{V_1}{V_2}\right)^{k-1}\right] \end{array} \right\}}{\left(1 - F\right)\left(1 - \dfrac{p_c}{p_1}\right)} \quad \text{. . -(5)}$$

an expression which, while it is formidable, can be used. We are now ready to figure theoretical efficiencies for any set of conditions and from them estimate the brake efficiencies, by using probable per cent of losses; that is, by departure from the theoretical cycle, by heat to water cooling and by the mechanical efficiency of the engine.

27 The reliability of this method is being checked by actual tests where they can be procured. For example, in Peabody's Thermodynamics, page 347, the theoretical efficiency of the Diesel cycle is given as 58%. We know by test that the water loss = 35% and the mechanical efficiency is 76%, hence, the brake efficiency = $58 \times (1\text{–}0.35) \times 0.76 = 28.6\%$. The actual efficiency by test = 28%.

We will allow for the regenerator engine a loss due to departure from the theoretical cycle of 10%, a water loss of 30%, a mechanical efficiency of 75%, giving a coefficient of 47½%, and for the regular cycle a departure from the cycle of 5%, a water loss of 35% and a mechanical efficiency of 80%, giving a coefficient of 48%.

Example: Let us take $p_1 = 400$ lb.; $p_c = 140$ lb.; $p_2 = 15$ lb.; all absolute. $k = 1.405$; $V_1 = 0.2$; $V_2 = 1$.

$$\text{From (2), } n = \frac{\text{Log } 400 - \text{Log } 15}{\text{Log } 1 - \text{Log } 0.2} = \frac{\text{Log } \dfrac{400}{15}}{\text{Log } 5} = 2.04$$

$$\text{From (1), } F^{\text{ max.}} = \frac{1 - \dfrac{0.405}{1.04}(1 - 0.2)^{1.04} - \dfrac{15}{400} \times \frac{1}{2}}{1 - \dfrac{140}{400}} = 77\tfrac{1}{2}\,\%$$

Maximum efficiency = 100 %.
For other regenerator efficiencies

$$\text{Eff.} = \frac{0.311 - F\,(0.209)}{(1 - F) \times 0.65}$$

from which, remembering the coefficient mentioned above:

Regenerator Efficiency Per cent	With equal compressions of 140 lb. abs. the expression for efficiency is	Theoretical Efficiency Per cent	Coefficient Per cent	Brake Efficiency Per cent	B.t.u. per b.h.p.-hr.
77.5	Theoretical Maximum	100	47.5	47.5	5038
70	$0.311 - .70 \times .209 \div (1 - .7) \times 0.65$	85	47.5	40.4	6300
65	$0.311 - .65 \times .209 \div (1 - .65) \times 0.65$	77	47.5	36.6	7000
60	$0.311 - .60 \times .209 \div (1 - .6) \times 0.65$	72	47.5	34.2	7450
55	$0.311 - .55 \times .209 \div (1 - .55) \times 0.65$	67	47.5	31.8	8000
50	$0.311 - .50 \times .209 \div (1 - .5) \times 0.65$	63.5	47.5	30.1	8500
0	Regular Gas Engine $= 1 - \left(\dfrac{V_1}{V_2}\right)^{0.405}$	47.9	48	23	11200

As a regenerator efficiency of 60% to 65% seems to be easily attainable, and 75% not impossible, it appears as if a heat consumption of 7000 B.t.u. could be obtained with commercial pressures.

28 Returning to the question as to whether a practical regenerator would cool the gases to the expected degree and realizing that in the cycles discussed instantaneous combustion presumably takes place,

while after-burning, that is, retarded combustion, is a necessary condition of practice, we will choose an example, showing the 60% regenerator with a compression of 140 lb. in which the same maximum temperature is delayed until $V_a = \frac{3}{10}$ whereby the highest pressure is reduced to about 285 lb. abs., if the heat added still equals $C_v(T_1 - T_c)$, from the efficiency given, the value of $C_v(T_3 - T_2)$ is obtained, T_3 being the absolute temperature of the exhaust. P_a and P_3 are likewise ascertained, and a new value of $n = 1.85$ results, and pressures corresponding to $V = \frac{4}{10}, \frac{6}{10}$ and $\frac{8}{10}$ are then derived. The card in Fig. 7, representing the approximate conditions of practice, is thus obtained.

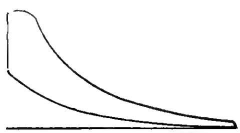


FIG. 7
GAS ENGINE CARD AS MODIFIED BY REGENERATOR

29 If a regenerator practically fulfills our conditions the final pressure P_3, derived from regenerator conditions, should not be higher than the value reduced from the theoretical efficiency.

30 It is probable that the temperature of the regenerator surfaces remains approximately constant throughout a cycle and that the returning gases issue at a constant temperature. This temperature is estimated as the peak temperature of the cycle, less the temperature withdrawn by the regenerator and that lost by work in the smaller cylinder before reaching the regenerator. Thus if $T_a = T_1$ = peak temperature = 2850° abs., $F(T_1 - T_c)$ = temperature regenerated $= \frac{6}{10}(2850 - 1000) = 1100°$. $\frac{\text{Efficiency}}{2}(T_1 - T_c)$ = temperature changed into work in the small cylinder, if made half by construction $= \frac{0.72}{2}(2850 - 1000) = 665°$.

31 T_R = temperature of issuing gas = 2850 − (1110 + 665) = 1075°; allowing for gas burned in the regenerator and irregularities,

T_R will be taken at 1200° abs., P_c = 140 lb., P_1 = 285 lb., all absolute. Atmospheric temperature = 75° $F.$ = 535° abs., T_a = 2390° $F.$ = 2850° abs., P_a = 269 lb., regenerator = 60%, $V_1 = \frac{2}{10}$, $V_a = \frac{3}{10}$, $V_1 = 1$. From Eff. $= 0.72 = \frac{(T_1 - T_c) - (T_3 - T_2)}{T_1 - T_c}$, T_3 is obtained and p_3 = 29.5 lb. reduced, n = 1.85 (from Equation 2), and from T_R = 1200°, a regenerator condition, the value of p_3 is figured. Each particle of gas issues at T_R and at the pressure of the cycle, then it is considered as expanding freely with the exponent k from its volume V to V_2, that of release, when it will have an individual temperature $T_3 = T_R\left(\frac{V_1}{V_2}\right)^{k-1}$ from $T\,V^{k-1} = T_1\,V_1^{k-1}$ = a constant.

32 The effect of each particle on the final result is measured by its individual temperature and by its individual weight. This density or weight varies as the pressure of the cycle, which pressure varies as the exponent n. The value of each particle is thus taken to equal $T_3 \times p$. The summation of these effects averaged, gives the T_3, from which the P_3 desired is reduced.

	Pressures		V	T_3 deg. fahr.	$T_3 \times p$	
p_1	285.0 lb.		2/10	631	180,000	
p_6		160.0 lb.	4/10	831		135,000
p_d		75.0 lb.	6/10	977		73,200
p_e		44.5 lb.	8/10	1090		48,500
p_3	29.5 lb.		1	1200	35,500	
	2)314.5 =	157.3 lb.			2)215,500 =	108,000
		436.8 lb.				364,700

$$T_3 = \frac{364{,}700}{436.8} = 835 \text{ deg. abs., or, } P_3 = 23.4 \text{ lb. abs.} = 8.4 \text{ lb. gage.}$$

By the efficiency method of Par. 31, P_3 was 29.5 lb. abs. = 14.5 lb. gage.

33 Why this result should be lower than that given by the efficiency method is not apparent. Possibly too much work is charged to the small cylinder and possibly delayed combustion, by keeping up the average pressure of the cycle, increases the refrigerating effect of after-expansion. The object of the calculation, to show that the condition of a practical regenerator will allow the theoretical low exhaust pressures to be obtained, seems to be sustained.

34 The temperatures of the regenerator surface that follow from the above figures are 640 deg. fahr. *low* and 640 deg. + 1110 deg. = 1750 deg. fahr. *high*.

35 A discussion of the effects of such temperatures on materials available for construction is invited.

THE ENGINE

36 An engine to carry out this cycle (shown in Fig. 8 and Fig. 9) consists of two equal cylinders of uneven strokes. The cylinders are connected by a free passage through a regenerator, and are provided with valves on the heads. These valves are operated by a revolving cam, driven by spiral gears and a shaft centrally placed. The cam forms the casing of the governor, which may move a circular cam plate, varying only the closing of the fuel valve, all valves being opened by the fixed cam. A loose-fitting valve, shown in section at the cool end of the regenerator, may be used to close the passage between the cylinders at appropriate times and is exposed only to moderate temperatures. Fly wheels, crank shaft, housing and water cooling are provided. The regenerator casing is arranged so that it may be removed bodily, with the containing regenerator elements, by removing several bolts. All valves and casings are the same. There are no small rods, pins or cotters between valves and cam, and the cylinder heads may be removed without disturbing the valves or their connection, pipe connections, of course, being excepted. Provision is made for an igniter, if it be required, and an opening, closed by a peep tube, is left on the upper side of the regenerator, so that if open it may vent the burning gases used for preheating it. The piston in the small cylinder moves 90° to 100° ahead of that in the large cylinder. The cylinder with full stroke is called the large cylinder. The cylinder with short stroke is called the small cylinder.

37 In operation, the regenerator being heated, a charge of air is drawn into the large cylinder while a charge of gas is drawn into the small cylinder. The air is compressed in the large cylinder and the gas in the small cylinder. The gas is discharged mainly into the regenerator, its volume being varied by the control over the closing of the gas valve by the governor. During this time the passage between the cylinders may be closed. As the small piston advances ahead of the large one, its cylinder is filled with hot gas too rich to burn. The opening of the communicating passage admits com-

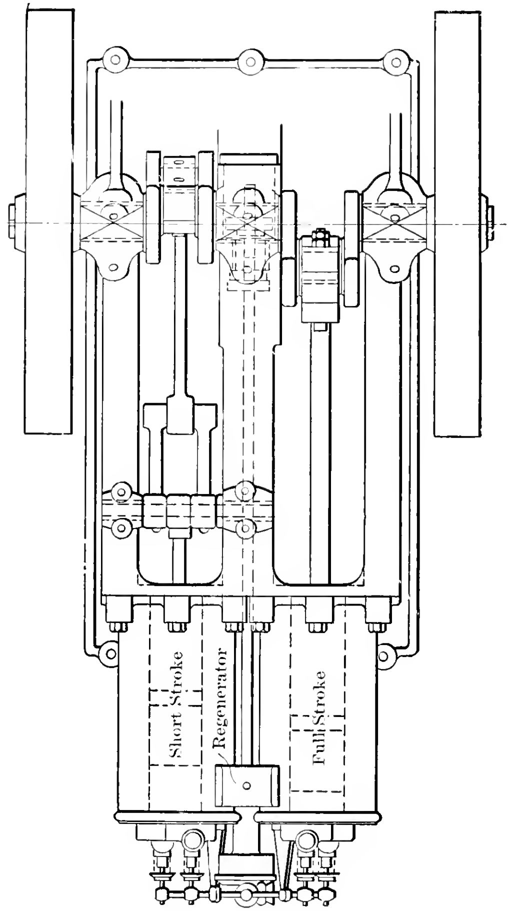
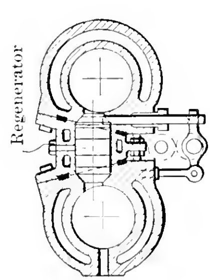


Fig. 8 Plain View of Engine



Section Through Cylinders and Regenerator

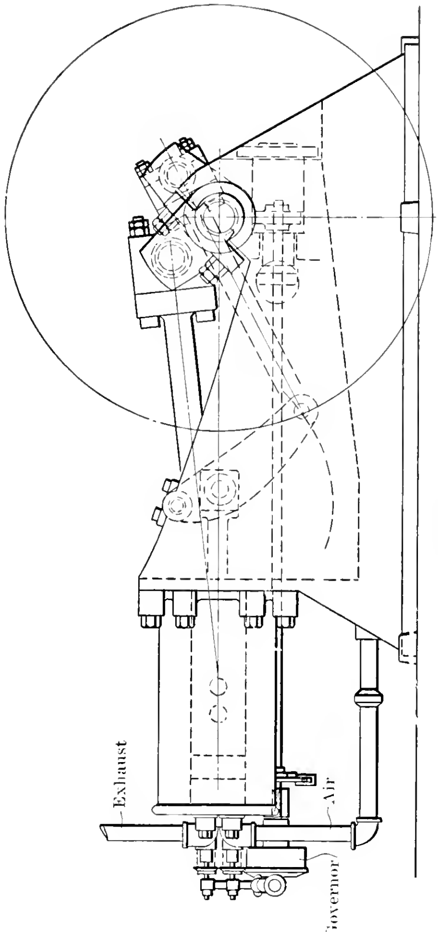
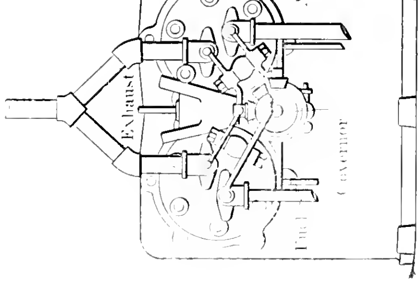


Fig 9 Side Elevation of Engine



pressed air, through the regenerator, at a high temperature and mixes it with the hot gas at the point of highest compression of the entire charge. Ignition takes place, spontaneously or otherwise, causing combustion with increased pressure. A power stroke follows, in the small cylinder only, as the large piston poises at its dead center. As this latter advances it aspirates the highly heated gases back into the large cylinder where they are further expanded and exhaust follows, from both cylinders if desired. The engine is designed to give equal power in each cylinder and it is claimed to have the following advantages:

a As there is no clearance in either cylinder, complete scavenging is possible.

b As the air and gas are compressed separately, preignition cannot occur.

c Both the gas and air being highly heated before mingling, combustion is rapid at the moment when the proper conditions exist. No mixture is required, as the gas is at first too rich to burn; then heated air sprays into a heated atmosphere of gas; and when exact chemical proportions are formed ignition should be spontaneous. Afterwards, excess heated air flows in, and if unburnt fuel exists it is intermingled on its return through the regenerator in contact with hot surfaces. These are exactly the conditions of perfect combustion.

d It has been shown that delayed combustion is probably advantageous to the engine, keeping up the pressures and increasing the cooling effect on the exhaust during after-expansion.

e By delaying the combustion, the high peak pressures are avoided. High pressures are not required and only good, ordinary workmanship is called for.

f To withstand the temperatures practicable in the regenerator we have infusible materials such as are used in electric furnaces, and alloys of nickel now used in the arts. Hardness is immaterial, as the regenerator elements can be cast or moulded without finish.

g The practical limit of temperature being located, engines for rich, expensive fuel, such as illuminating gas, will have 50% increased economy for equal compression.

h While for weak fuels not now developing the limiting temperature, an equally high economy is available, with

increasing power, as the regenerator furnishes the heat units that the fuel lacks.

i Hydrocarbons are applicable by simple injection into the regenerator at the proper time.

j The low percentage of heat lost to water cooled surfaces, which is essential to this cycle seems, evidently, to be provided for in this design, as the high temperature gases are present only in the small cylinder, with its small amount of surface, while only a part of their weight remains throughout the stroke. In the large cylinder the temperatures are low, and the regenerator may be insulated. The design of this engine appears to be simple, and as the troubles due to imperfect mixtures and failure to ignite seem to be absent, regularity and certainty of operation should follow. Like the compound engine, the extra cylinder is the penalty paid for high economy.

38 Specific discussion of regenerators, their construction and effect, appears to be lacking in recent mechanical literature. Those who have a reasonable doubt that high-efficiency regenerator effect can be obtained in engine construction, may refer to an engine experiment made by Sir William Siemens[1] as far back as 1852, wherein the heat waste was one-twentieth; that is, the efficiency equalled 95%. Reference is also made to a test by Prof. Norton,[2] with a determination of heat waste equal to one-tenth, or an efficiency of regenerator equal to 90%.

[1]Rankine's Steam Engine, p. 345.
[2]Rankine's Steam Engine, p. 358.

GAS POWER SECTION

PRELIMINARY REPORT OF LITERATURE COMMITTEE (II)

ARTICLES IN PERIODICALS

AIR-COMPRESSORS, RATEAU CENTRIFUGAL, Frank Koester. *Engineering News, January 20, 1910.* $2\frac{1}{2}$ pp., 7 figs., 3 curves. *bc.*

Of great interest in connection with the gas turbine problem.

AIRSHIP EXHIBITION, FRANKFURT A.M., INTERNATIONAL. *Zeitschrift der deutscher Ingenieure, March 5, 1910.* 3 pp., 7 figs. *bB.*

Description of several airship gas motors.

CAST-IRON UNDER HIGH TEMPERATURES, PERMANENT EXPANSION OF. *Power, January 11, 18, 25, 1910. cf.*

Several investigators have been prompted to search at this time, chiefly for superheated steam. Three papers were read before the Society in Boston; also tests by The Crane Company, May 1909.

COMBUSTION, CHEMICAL AIDS TO. *Power, February 15, 22, 1910.* $\frac{1}{2}$p. *ac.*

Editorial reviewing catalytic theory of H. J. Williams. Also discussion of Mr. Williams' paper before the Society of Chemical Industry.

ELECTRICAL CONDUCTIVITY OF FLAMES CHARGED WITH METALLIC SALTS, M. U. Gouttefangeas. *Annales de Chimie et Physique, August 1909.* 11 pp., 1 fig., 4 tables. *c, scientific.*

Physical determination, with brief guide to the general subject.

ENGINE AND STARTING ENGINE, FOUR-CYLINDER OIL. *Engineering (London), January 28, 1910.* 2 pp., 11 figs. *bC.*

Made by Griffin Engineering Company, Bath, England; 70-h.p. crude oil engine with compressor and 5-h.p. engine for starting.

ENGINES AT BARROW STEEL WORKS, BLAST-FURNACE GAS. *Engineering (London), April 29, 1910.* 2 pp., 6 figs. *bB.*

Made by Richardsons, Westgarth & Co.

Opinions expressed are those of the reviewer, not of the Society. Articles are classified as: *a* comparative; *b* descriptive; *c* experimental; *d* historical; *e* mathematical; *f* practical. A rating is occasionally given by the reviewer, as *A*, *B*, *C*. The first installment was given in The Journal for May 1910.

ENGINE BUILT BY SULZER, DIESEL MARINE. *Die Gasmotorentechnik, February 1910.* 3 pp., 4 figs., 1 curve. *C.*

Description of 4-cylinder Diesel motor and account of results with a 150-h.p. motor.

ENGINES, CONSTRUCTIVE DETAILS OF DOUBLE-ACTING FOUR-CYCLE GAS, R. Drawe, Schleifmühle-Saarbrücken. *Zeitschrift der Verein deutscher Ingenieure, February 12, 19, 1910.* 10 pp., 34 figs. *bfA.*

Interesting account of improvement in design of cylinders, pistons, crossheads, valve gear, exhaust valve, water cooling and ignition of Ehrhardt and Scheuer gas engine.

ENGINE, DE LA VERGNE CRUDE OIL. *Engineering News, January 13, 1910.* $1\frac{1}{2}$ pp., 3 figs., 1 table, 1 curve. *bc.* Also *Power, January 25.* 2 pp., 6 figs., 1 curve. *b.*

A compromise between Diesel and Hornsby-Akroyd. Operates upon a modified Diesel cycle, with lower pressures. Less than $\frac{1}{2}$ lb. oil per b.h.p.-hr. Self-ignitive.

ENGINE, DEVELOPMENT OF THE KOERTING GAS, E. Koerting, Jr. *Zeitschrift der Verein deutscher Ingenieure, January 8, 1910.* 1 p. *bC.*

Lecture by E. Koerting, Jr., Hanover. Description of the Koerting 4-cycle engine of smaller sizes.

ENGINES FOR NAVIGATION, CRUDE OIL. *Die Gasmotorentechnik, November 1909.* 2 pp., 1 fig. *bB.*

Description of 120-h.p. gas motor built for Slomann & Co., Hamburg, by Germania Werft Stetten.

ENGINE, FOUR-CYLINDER HIGH-SPEED GAS. *The Engineer (London), April 29, 1910.* $1\frac{1}{2}$ pp., 5 figs., 1 table. *bC.*

Made by Anderston Foundry Company of Glasgow and Middlesborough for direct connection to electric generators.

ENGINES, IGNITION IN GAS. *Annales des Mines de Belgique, Third Quarter, 1909.* Also *Annales des Travaux Publics de Belgique, 1909.*

Review of a French book by G. Yseboodt, engineer of the Belgian State Railways and director of l'Ecole Industrielle de Tubize. 8vo, 108 pp., 123 figs. A prize winner in 1903–1905.

ENGINE INDUSTRY DURING THE LAST FIVE YEARS, DEVELOPMENT OF THE GAS, E. Hubendick. *Gasmotorentechnik, December 1909.* $3\frac{1}{2}$ pp., 2 tables. *deB.*

Account of a publication in "Bihang till Jernkontorets Annaler" of the number and capacity of large gas engines built.

ENGINE INSTALLATIONS IN EUROPE, NOTABLE GAS. *Engineering Magazine, February 1910.* 8 pp. *abdf.*

A series of halftone illustrations with descriptive captions.

ENGINE, MOTOR BOAT, Ernst Valentin, Berlin. *Die Gasmotorentechnik, December 1909.* 2 pp., 4 figs. *bB.*

Description of 4-cylinder and 8-cylinder motors built by Dürkopp & Co., Bielefeld.

ENGINE (MARINE), REVERSING CRUDE OIL. *Power, February 22, 1910.* 1 p., 2 figs. *b.*

Reversing gear described in detail.

ENGINE, TEST OF GAS, C. C. Winn. *Power, January 11, 1910.* 3 pp., 1 table, 8 curves, many indicator cards. *c.*

Speed is the basis to which the investigation relates. All results are stated in terms of varying speed. Tabular data are given. The curves drawn upon these data are badly forced and are quite deceptive.

ENGINE, THE COOPER GAS. *Power, January 11, 1910.* 2 pp., 4 figs. *bf.*

Double-acting, four-cycle engine, built by C. & G. Cooper, Mt. Vernon, O. Tandem cylinders.

ENGINE PISTON-RODS, LETTER ON WEAR OF GAS. N. Auchenbach. *Power, January 11, 1910. cf.*

Gives data as to cleansing gas of sulphur by use of oxide scrubber.

ENGINE, THE MODERN GAS, A. M. Levin. Review by Prof. L. S. Marks. *Engineering News, February 17, 1910.*

ENGINE, 2000-h.p. SINGLE-CYLINDER GAS. *Power, January 25, 1910.* 2 pp., 4 figs. *b.*

Koerting blowing engine, built by Siegen, Germany. 43½ in.-100½ in. x 55 in. tandem.

FUELS, GASOLENE AND ALCOHOL AS MOTOR, Robert M. Strong. *Engineering Magazine, January 1910.* 3 pp.

Abstract of Bulletin No. 392 issued by the United States Geological Survey, covering 200 comparative tests.

FURNACES, PRODUCER-GAS FIRED, Oskar Nagel. Review by Dr. C. E. Lucke. *Engineering News, February 17, 1910.*

INTERNAL-COMBUSTION ENGINE, DOUBLE-ACTING TWO-CYCLE. *The Engineer (London), February 18, 1910.* 3pp., 2 figs. *bcC.*

Made by Johnson's Motor Works, Harrogate. Differential pistons, no valves.

INTERNAL-COMBUSTION ENGINES, ELECTRIC IGNITION OF, John W. Warr. *Electrical Engineer (London), November 5, 1909.* 4½ pp., 8 figs. *bB.*

Paper presented before Institute of Electrical Engineers, Manchester Local Section, November 2, 1909.

INTERNAL-COMBUSTION MARINE ENGINES, Linton Hope. *Engineering (London), April 1, 1910.* $3\frac{2}{3}$ pp., 18 figs., 2 tables. *A.* Also *April 8*, b.h.p. table. $\frac{1}{2}$ p. *B.*

Installation of Petrol Motors on Fishing Boats, with tables of dimensions of boats and motors.

LOW-TENSION IGNITION GEAR, GAS ENGINE. *Electrical Engineer (London), January 28, 1910.* $1\frac{1}{2}$ pp., 5 figs. *bC.*

Description of Ignition Gear made by Felton & Guilleaume Lameyerwerke, A. G., Frankfort a. M.

MOTOR CAR FOR OREGON S.L.R.R., GASOLENE. *Engineering News, January 20, 1910.* 1 p. *b.*

200-h.p. car, designed by W. R. McKeen.

PLANT, LOG OF A RAILWAY GAS-POWER. *Power, April 12, 1910.* $2\frac{1}{2}$ pp., 3 tables, 2 curves. *f, commercial.*

Two 800-h.p. units. The plant operates 24 hours per day, every day in the year.

PRODUCER AND ENGINE PLANT, TEST RUN OF, Wm. O. Webber. *Power, February 8, 1910.* 4 pp., 4 figs., 1 table, 3 curves. *bf.*

Thirty-day acceptance run at Soldiers' Home, Chelsea, Mass.

PRODUCER, A SIMPLE BITUMINOUS GAS. *Power, February 1, 1910.* 2 pp. *bf.*

100-h. p. auction producer; ran for six 24-hour days per week for two years, without repairs.

PRODUCER, BODY SUCTION GAS. *Indian and Eastern Engineer, November 1909.* 1 p., 1 fig. *bC.*

Description of producer made by Messrs. Robert Body, Ltd., Bury St., Edmunds, Suffolk, England.

PRODUCER, BITUMINOUS-FUEL SUCTION GAS. *Engineering News, March 31, 1910.* $\frac{1}{2}$ p., 1 fig. *b.*

Reprint from Engineering Review (London). The Morton producer, Birmingham, England. Volatile matters fixed in the coked part of fire.

PRODUCER, CONTROL OF WATER FEED GAS, Frank P. Peterson. *Power, February 15, 1910.* 1 p. *f, general.*

Abstract of paper read before the National Gas and Gasolene Engine Trades Association.

PRODUCER-GAS PLANT, SMALL ISOLATED, Osborn Monnett. *Power, January 11, 1910.* 3 pp., 7 figs. *bf.*

Consists of two-wile suction producers, 100 and 115-h.p., rated capacity, and two Bruce-Macbeth 4-cylinder vertical engines. Anthracite pea coal.

PRODUCER-GAS POWER IN THE UNITED STATES, DEVELOPMENT OF, Prof. R. H. Fernald. *Power, March 1, 1910.* 1 p. *acf.*

Extracts from Bulletin No. 416 issued by the United States Geological Survey. Presents summarized results from tests of 75 coals, 6 lignites, 1 peat.

PRODUCER GAS, REMODELING GASOLINE ENGINES FOR, H. F. Smith. *International Marine Engineering, October 1909.* 2 pp. *bB.*

Paper before National Gas and Gasolene Engine Trades Association, June 1909. Points for design.

PRODUCER, TEST OF SUCTION GAS, Garland and Kratz. *Power, January 4, 1910.* 3 pp., 2 figs., 4 tables, 1 curve. *b.*

Reprint from Transactions. Concerns labor-saving methods of testing.

PRODUCER, THE HILL BITUMINOUS GAS. *Power, January 18, 1910.* 1 fig. *bf*

Combination of down-draft and up-draft principles.

PRODUCER, OIL-GAS, A. B. Davis. *Power, January 4, 1910.* 2 pp., 3 figs., 2 tables. *bcf.*

Abstract of paper before Ohio Society of Engineers. Good discussion of chemical reactions. Producer admits air to retorts, to prevent formation of tar. Heat efficiency: retorts, 89.8%; producer, 65.1%.

PUMP, HUMPHREY GAS. *Engineering Magazine, January 1910.* 2½ pp., 1 fig. Also *Engineering (London), February 11, 1910.* 1½ pp., 2 curves. *bce.*

Abstract of paper before the British Institution of Mechanical Engineers. Direct explosion pump applied to air compression. Describes action briefly and discusses forces acting, pressures produced and probable capacity and efficiency.

PUMPING WITH GASOLENE ENGINES. *Engineering Record, February 26, 1910.* ½ p., 1 table, 1 curve. *c.*

Abstract of governmental report of tests made in 1905 in California by J. N. LeConte and C. E. Tait

PUMPS, DIRECT-EXPLOSION. *Engineering Record, February 12, 1910.*

A letter from W. H. Smyth, dates and patent-numbers.

TURBINE (GAS-TURBINE) CONSTRUCTION, PRACTICAL STUDY IN OIL, Chas. Lemale. *La Technique Moderne, September 1909.* 5 pp., 5 figs., 6 curves. *bcfA.*

Full description of a most remarkable attempt at the internal-combustion prime-mover turbine built by the Baden Society for Combustion Turbo-Motors, after designs by Professor Rateau. The speed was 4000 r.p.m., the working pressure 70 lb., the compressor a 6-stage fan having a maximum efficiency of 70% and a capacity of 140,000 cu. ft. per hr. The curves characteristic of efficiency, etc., have been reproduced on too small a scale to be intelligible and the text line does not enlighten; but the photographs, expansion-curves, etc., are clear.

TURBINE, THE GAS, A. W. H. Griepe. *Power, March 8, 1910.* 3 pp., 6 figs., 1 table. *bcf.*

Discusses two suggested plans for turbine acted on directly by the exploded gases, one by Wegner and one by Griepe.

GENERAL NOTES

NATIONAL ASSOCIATION OF MANUFACTURERS

The National Association of Manufacturers held its fifteenth annual meeting, May 16–18, at the Waldorf-Astoria, New York. The proceedings covered questions of governmental policy, foreign relations, the tariff, patents, immigration, internal commerce, waterways, merchant marines, conservation of resources, etc., on which reports were made by committees. Attention was also given to industrial accidents and liability insurance. An illustrated lecture was delivered by Prof. F. R. Hutton, Honorary Secretary, Am. Soc. M. E., on The Prevention of Industrial Accidents. John Kirby, Jr., president, and F. H. Stillman, Mem. Am. Soc. M. E., treasurer, were re-elected.

NATIONAL ELECTRIC LIGHT ASSOCIATION

At the St. Louis convention of the National Electric Light Association, May 23–27, 1910, among the reports of standing committees, presented as part of the regular business, was that on Gas Engines, by I. E. Moultrop, Mem. Am. Soc. M. E., Chairman; and that on National Conservation, by Dudley Farrand, Mem. Am. Soc. M. E., Chairman.

Among the papers presented at the general and technical sessions were: A New Form of Tungsten Lamp, C. F. Scott; Water Intake from the Mississippi River for Two Electric Generating Stations in St. Louis, John Hunter, Mem. Am. Soc. M. E.,; Decentralized Steam Plants, R. D. DeWolf; Space Economy of Turbo-Generators, Paul M. Lincoln, Mem. Am. Soc. M. E.; Gas Engine Plants for Central Stations, Nisbet Latta, Mem. Am. Soc. M. E.; Feeder Regulators, E. E. Lehr; Direct-Current Turbo-Generators, W. L. Waters, Mem. Am. Soc. M. E.; Interesting Points in Modern Transformers, L. T. Robinson; The High-Efficiency Lamp, S. E. Doane. At the sessions of the new power transmission section, papers were given on The Public and the Water Powers, Henry L. Doherty, Mem. Am. Soc. M. E.; Present Problems of Water Transmission, Harold W. Buck; Modern Power-Transmission Systems, C. F. Scott; Electrical Phenomena of Transmission at High Voltages, C. P. Steinmetz, Mem. Am. Soc. M. E.

A special address was made on the evening of the association's twenty-fifth anniversary, by Past-President Samuel Insull, on Twenty-Five Years' Central Station Commercial Development.

AMERICAN WATER WORKS ASSOCIATION

The annual convention of the American Water Works Association was held at the Grunewald Hotel, New Orleans, La., April 26–30, 1910. Reports were

received at the opening sessions from committees on Publication, Electrolysis, Fire Protection, Water Works Standards, Depreciation, Reorganization in addition to the regular annual reports and accounts. Papers were presented on the Use of Electricity in Water Works Pumping, Charles B. Burdick; Legal Decisions, H. B. Rudisill; Methods of Handling Meters in Service, A. W. Cuddeback; The Conservation of Potable Waters, J. M. Diven; The Cost of Furnishing Water, Daniel W. Mead, Mem. Am. Soc. M. E.; A Coöperative Water Works Franchise, John W. Alvord; Municipal Ownership, Park Woodward; Baltimore County Ozonation Plant, A. E. Walden; The Danger of Contamination of Water Supply by Back Pressure from Fire Pumps, Alexander Milne; Suggestions as to Water Works for Fire Efficiency, W. H. Glore; Municipal Water Softening, Alexander Potter; Advertising the Water Works Business, D. R. Gwinn; The Settling Basins at Richmond, Va., E. E. Davis; The Fire Service Water Works of Winnipeg, H. N. Ruttan.

AMERICAN SOCIETY OF NAVAL ARCHITECTS

At the annual dinner of the American Society of Naval Architects, held at Rauscher's, Washington, D. C., May 7, 1910, addresses were made by the president, Engineer-in-Chief H. I. Cone, U. S. N.; the Secretary of the Navy; Hon. Joseph G. Cannon, Speaker of the House; Rear-Admiral Richard Wainwright; nd L. P. Padgett and Ernest W. Roberts of the Congressional Committee in he Navy.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

The American Institute of Chemical Engineers held its semi-annual meeting June 22–24, 1910, at the Hotel Clifton, Niagara Falls, Canada. Papers were presented on the Corrosion of Iron and Steel and its Prevention, G. W. Thompson; Chemical Engineering Education, F. W. Frenchs; Manufacture and Industrial Applications of Ozone, Oscar Linder; Underground Waters for Manufacturing Purposes, W. M. Booth; Loss in Coal due to Storage, A. Bement, Mem. Am. Soc. M. E.; Plant Design, W. M. Grosvenor; and others.

THE INSTITUTION OF CIVIL ENGINEERS

A pamphlet has just been issued by the Institution of Civil Engineers, showing the architectural design of the institution's new building, to be erected at the corner of Great George and Princes Streets, on an area of 31,000 sq. ft. In style it is a modern rendering of the later Renaissance and pieces of timber and products brought from various parts of the British Empire, symbolic of the close relationship of the members of the institution, will be introduced into its construction. The plan of the building provides for council and committee rooms, reading rooms, and general offices on the ground floor, a lecture theatre, the great hall and the main library on the first floor, and on the second floor further library accomodations as well as writing and smoking rooms for the members. The basement and the third floor will be given up to provision for the general service of the premises.

The institution, which was established in 1818 and now numbers 9,136 members, is obliged to remove from its present headquarters because of the extension of the government offices. The erection of the new building affords an opportunity to meet and forestall in a comprehensive manner present and future needs in a building worthy of the prestige to which the society has attained.

INTERNATIONAL AMERICAN SCIENTIFIC CONGRESS

The International American Scientific Congress, which will hold its meeting for 1910 in Buenos Aires, Argentine Republic, July 10–25, will be divided into eleven sections: engineering; physics and mathematics; chemistry; geology; anthropology; biology; geography and history; economics and statistics; military science; naval science; psychology.

THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

A special meeting of the American Institute of Electrical Engineers, held in New York, May 27, 1910, was conducted by the Railway Committee of the Institute. Papers were read on the Electric Railway Catenary Trolley Construction by W. N. Smith, electric traction engineer with Westinghouse, Church, Kerr & Company; and The Application of Porcelain to Strain Insulators by Willard H. Kempton of the Ohio Brass Company of Mansfield, O.

The annual convention is now in session at the Waumbek Hotel, Jefferson, N. H.

AMERICAN INSTITUTE OF MINING ENGINEERS

A meeting of the American Institute of Mining Engineers will be held next fall in the Canal Zone, Panama, probably early in November. Besides the trip to and from the Isthmus it is proposed to include, among other possible stops en route, a visit to the mines and works of the Spanish-American Iron Company on the north shore of Cuba. Letters have been received from President Taft and from Colonel Goethals, the engineer in charge, which assure the institute of a cordial reception and a profitable as well as a delightful excursion.

NATIONAL MACHINE TOOLBUILDERS ASSOCIATION

The semi-annual convention of the National Machine Toolbuilders Association was held May 24 and 25 at Rochester, N. Y. F. A. Geier, Mem.Am.Soc. M.E., president of the association, called the meeting to order and congratulated the members on the progress made and the mutual good feeling engendered. Papers were read by Prof. F. B. Dyer, superintendent of the Cincinnati public schools, on the Work of the Cincinnati Continuation School, illustrated with stereopticon views; by Robert Pierpont, on the Future of the Automobile Business with Reference to Machine Tools; and by Wm. R. Wood, on a Court of Patent Appeals. R. K. LeBlond, Mem.Am.Soc.M.E., and Wm. Lodge, Mem.Am.Soc.M.E., discussed the relative merits of the cone drive and gear drive.

ILLUMINATING ENGINEERING COURSE AT JOHNS HOPKINS UNIVERSITY

Johns Hopkins University announces a course of thirty-six lectures on Illuminating Engineering, extending from October 26-November 8, 1910, arranged upon the initiative of the Illuminating Engineering Society, 29 West 39th Street, New York.

The lectures, which will be given under the joint auspices of the society and the university, will follow immediately the annual convention of the society to be held at the university, Monday, October 24, 1910. The course has three objects: (*a*) to indicate the proper coördination of those arts and sciences which constitute illuminating engineering; (*b*) to furnish a condensed outline of study suitable for elaboration into an undergraduate course for introduction into the curricula of undergraduate schools; (*c*) give practicing engineers an opportunity to obtain a conception of the science of illuminating engineering as a whole. The university will provide facilities for demonstrations at the lectures and will also have installed a working exhibit of apparatus for experimental work in light, illumination and illuminating engineering.

Among the lecturers announced are Edward P. Hyde, President Illuminating Engineering Society; Charles P. Steinmetz, Mem. Am.Soc. M.E., Professor of Electrical Engineering, Union University; Alexander C. Humphreys, Mem. Am.Soc.M.E., President Stevens Institute of Technology; A. G. Glasgow, London, England; L. B. Marks, New York; John W. Lieb, Jr., Mem.Am.Soc. M.E., New York; Walton Clark, Mem.Am.Soc.M.E., President Franklin Institute.

AMERICAN RAILWAY ASSOCIATION

At the annual meeting of the American Railway Association, held in the Engineering Societies Building, 29 West 39th Street, New York, on May 18, reports were received from committees on Maintenance, on Relations between Railroads, on Safe Transportation, on Explosives, and on Electrical Working. Delegates were appointed to the International Railway Congress and the following officers elected: president, Daniel Willard; vice-president, H. V. Mudge; members of the executive committee, C. R. Gray, I. G. Rawn.

WESTERN RAILWAY CLUB

The annual meeting of the Western Railway Club was held in the Auditorium Hotel, Chicago, on Monday, May 16. The following officers were elected for the year 1910-1911: J. F. DeVoy, president; C. B. Young, first vice-president; T. H. Goodnow, second vice-president; J. W. Taylor, secretary-treasurer; H. LaRue, G. H. Bryant, W. B. Hall, directors; D. L. Barnes, W. F. M. Goss, Mem. Am.Soc.M.E., C. A. Seley, F. W. Sargent, trustees.

An illustrated lecture on Early Railroading in Chicago was given by Frank L. Smith.

PERSONALS

Geo. O. Baker has severed his connection with the New England Engineering Co., with whom he has been associated as chief engineer, and has taken offices at 35 Wall St., as consulting and supervising engineer.

William O. Barnes, until recently assistant superintendent of the Miller Lock Co., Philadelphia, Pa., has accepted a position with the Iver Johnson Arms and Cycle Works, Fitchburg, Mass., as mechanical engineer.

Geo. H. Baush has resigned his position as general manager of the Fay Machine Tool Co., Philadelphia, Pa.

Grant D. Bradshaw, consulting engineer, Chicago, Ill., has become assistant steam engineer of the Cambria Steel Co., Johnstown, Pa.

Charles E. Bruff has severed his connection with the Power and Mining Machinery Co., New York, to look after the engineering work for the Chino Copper Co., Santa Rita, New Mexico.

John J. Chisholm, recently chief engineer of the Waterside station of the New York Edison Co., has become associated with the Westinghouse Electric Manufacturing Co., East Pittsburg, Pa.

A. C. Davis has resigned his position as master mechanic of the Pennsylvania Lines, Wellsville, O., and has purchased an interest in the American Manuufacturing Concern, Jamestown, N. Y.

E. W. Dean has become connected with the Boston factory of the United Printing Machinery Co. He was formerly in the service of the Kidder Press Co., Dover, N. H.

Edward P. Decker recently factory manager of the Kemiweld Can Co, Detroit, Mich., has associated himself with Ernest M. Baker, under the firm name of E. P. Decker & Co., and will conduct a general engineering and construction business, with offices in Detroit, Mich.

Harry W. Henes has become associated with A. Bolter's Sons, Chicago, Ill.

Paul L. Joslyn, recently identified with the Minneapolis Steel and Machinery, Co., Minneapolis, Minn., has become associated with the Nordberg Manufacturing Co., Milwaukee, Wis.

Frederick Lane, formerly superintendent of Jenkins Brothers, Ltd., Montreal, Canada, now occupies a position with the Railway Signal Co. of Canada, Ltd., in the same capacity.

J. R. McColl, of the engineering department of the American Blower Co., Detroit, Mich., has severed his connection with that company in order to become a member of the new firm of Ammerman, McColl & Anderson, Detroit, Mich., which will conduct a consulting engineers practice.

Harold T. Moore, formerly production engineer of the Bridgeport Brass Co., Bridgeport, Conn., has become identified with the Cruse-Kemper Co., Ambler, Pa.

Charles L. Newcomb, Jr., is now connected with the engineering department of the Denver Rock Drill & Machinery Co., Denver, Colo. Until recently Mr. Newcomb was with the International Steam Pump Co., with whom the Denver Co. is very closely associated.

Robert B. Owens, recently on the engineering staff of the Southern Power Co., Charlotte, N. C., has been appointed secretary of the Franklin Institute, Philadelphia, Pa.

James Posey, recently associated with Henry Adams, Baltimore, Md., as assistant engineer, has become consulting engineer of the firm, Painter & Posey, of the same city.

N. S. Reeder, formerly identified with the Canada Car Co., Ltd., Montreal, Canada, in the capacity of general manager, has become associated with the Western Steel Car and Foundry Co., Chicago, Ill.

Arthur L. Robinson has been appointed superintendent of the mechanical division of the Panama canal by Geo. W. Goethals, and as such will have charge of all the machine shops in the canal zone, where the tools used in the work are built and repaired.

A. L. Saltzman, formerly in charge of the drafting department of Walter Scott & Co., Plainfield, N. J., has become identified with the Edison Company's Laboratory, Orange, N. J.

P. S. Steenstrup, formerly manager of the Hyatt Roller Bearing Co., Harrison, N. J., has been appointed manager of the new branch of the Columbia Motor Car Co., at Seattle, Wash.

Robert L. Streeter has been appointed assistant professor of mehanical engineering, Rensselaer Polytechnic Institute, Troy, N. Y. He was formerly instructor of machine design of the Buffalo Technical High School, Buffalo, N. Y.

Ambrose Swasey has received the degree of Doctor of Science from Dennison University, Dayton, O.

Leroy Tabor has resigned his position as superintendent of the Tabor Manufacturing Co., Philadelphia, Pa., to accept a position with the Morrow Manufacturing Co., Elmira, N. Y.

Howard E. Troutman has become associated with the International Steam Pump Co., as assistant sales manager of the Chicago, Ill., office.

Merton G. White, formerly manager of sales department of A. D. Granger Co., New York, has been appointed manager of the New York office of the Fitchburg Steam Engine Co.

The degree of Doctor of Science was conferred by Columbia University upon Sir William H. White, K. C. B., Honorary Mem. Am. Soc. M. E., at the annual Commencement on June 1.

H. L. Whittemore, associate professor in theoretical and applied mechanics, University of Illinois, Urbana, Ill., has received the appointment of engineer of tests in the Ordnance Department of the U. S. Government at Watertown Arsenal, Watertown, Mass.

Fred. M. Whyte, who has been chief mechanical engineer of the New York Central Lines, has been appointed general manager of the New York Air Brake Co., with headquarters at Watertown, N. Y.

C. T. Wilkinson, of the power and mining machinery department of the General Electric Co., Schenectady, N. Y., has left this country for a visit of several months to England and France for the purpose of investigating the high-tension transmission situation.

E. E. Wood, until recently president and manager of the Walcott & Wood Machine Tool Co., Jackson, Mich., will be factory manager of the new Grant & Wood Manufacturing Co.

CURRENT BOOKS

Principles and Practice of Ironfounding. By E. L. Rhead. *Manchester England, Scientific Pub. Co., 1910.* Cloth, 8vo, 505 pp. Price, 7s., 6d.

Contents: Iron and Steel in the Foundry; Testing Cast Iron; Moulding Materials in the Foundry; Sand-Mixing Appliances in the Foundry; Foundry Blackings and Partings; Moulding Tools and Appliances; Moulding Operations; Cores and Core Making; Loam Moulding; Plate and Machine Moulding; Chill Castings; Malleable Castings; Melting Iron for Foundry Purposes; Blast for Cupolas; Air Furnaces; Appendix.

The Reinforced Concrete Pocket Book. By L. G. Mensch. *San Francisco, Cal., Neal Pub. Co., 1909.* Morocco, pocket size, 216 pp. Price, $10.

Contents: Useful Tables, Rules and Illustrations for the Convenient Design, Rational construction and Ready Computation of Cost of Reinforced Concrete Girdles, Slabs, Footings, Columns, Buildings, Retaining Walls, Tanks, Grain Elevators, Coal Bins, Water Pipes, Sewers, Dams, Bridges, Smoke Stacks, Piles, etc.

Annual Report of the Water Supply Commission of Pennsylvania, 1908. *Harrisburg, C. E. Aughinbaugh, 1910.* Cloth, 8vo, 109 pp., illustrated.

Contents: Inactive Water Companies; Obstructions to Streams, Methods of Bank Protection; Rainfall; Droughts, the Drought of 1908; Floods during 1908; Report of the Engineer of the Commission upon the Causes and Methods of Relief from Floods in Turtle Creek, Westmoreland and Allegheny Counties.

ACCESSIONS TO THE LIBRARY

This list includes only accessions to the library of this Society, included in the Engineering Library. Lists of accessions to the libraries of the A. I. E. E. and A. I. M. E. can be secured on request from Calvin W. Rice, Secretary, Am.Soc.M.E.

American Society of Mechanical Engineers. Year Book, 1910. *New York, 1910.*

Annual Library Index, 1909. *New York, 1910.*

Baylor University. Home-Coming of Baylor University. (Bulletin No. 1, Vol. 13.) *Waco, 1910.*

Boiler Troubles and Their Treatment. By G. W. Wood. *Philadelphia, 1910.* Gift of author.

Forest Nursery and Reforestation Work in Massachusetts. By R. S. Langdell. *Boston, 1910.* Gift of Massachusetts State Forester.

Königliche Technische Hochschule zu München. Bericht uber das Studienjahr, 1908-1909. *Munich, 1910.*

———Program 1909-1910. March 1910. *Munich, 1910.*

Maryland Conservation Commission. Report 1908-1909. *Baltimore, 1909.* Gift of the Commission.

Maschinen-Elemente. Vol. 1–2. By C. Bach. *Leipzig, 1908.*

Massachusetts State Forester. 6th annual report. *Boston, 1910.* Gift of Massachusetts State Forester.

McGill University. Bulletin, *January 1910. Montreal, 1910.*

Municipal Franchises. Vol. 1. By D. E. Wilcox. *Rochester, 1910.*

New York City Board of City Magistrates. Annual Report, 1909. *New York, 1910.* Gift of the board.

Principles and Practice of Iron Founding. By E. L. Rhead. *Manchester, England, Scientific Pub. Co., 1910.*

Schweizerische Bauzeitung. Vol. 55-date. *Zurich, 1910-date.*

Smoke Prevention in Steam Boiler Plants. By H. D. Frary. (Reprinted from Minnesota Engineer, March 1910.) Gift of author.

Story of a Tariff: the Tariff Act of 1909. Gift of J. H. Gallinger.

Technical League. Bulletin. Vol. 1–2, No. 4. August 1909–April 1910. *New York, 1909–1910.* Gift of the league.

Troisieme Congrès International Aeronautique, Milan, 22–28 Octobre, 1906. Rapports et Memoires. *Paris, 1907.*

EXCHANGES

Experiment Station Record. Vol. 20–21. *Washington, 1908–1909.*

United States Navy Department. Message of the President, 1863. *Washington, 1863.*

———Report of the Secretary. 1862, 1866, 1868, 1871, 1874, 1875, 1877, 1879, 1881, 1882, Vol. 1–2, 1883, Vol. 1–2, 1884, Vol. 1–2, 1886, 1888, 1889, pts. 1–2, 1890–1897, 1898, Vol. 1–2, 1900, 1902–1908. *Washington, 1862–1908.*

———Report of Board on Comparative Trials of the Scout Cruisers, Birmingham, Salem, Chester, December 22, 1909. *Washington, 1910.*

Western Society of Engineers. Year Book, 1910. *Chicago, 1910.*

TRADE CATALOGUES

Acme Machine Co., *Cleveland, O.* Bolt, nut and forging machinery, 162 pp.

Bardons & Oliver, *Cleveland, O.* Turret lathes and machinery, 302 pp.

Blake & Knowles Steam Pump Works, *New York, N. Y.* Bulletin B-K, 843, Open feed heater, 12 pp.

Butterfield & Co., *Derby Line, Vt.* Taps, stocks and dies, screw plates, reamers, tools for steam fitters, etc., 90 pp.

Hannoversche Maschinenbau-Actien-Gesellschaft, *Hannover-Linden.* 4-cylinder balanced compound locomotives, 26 pp.

Industrial Instrument Co., *Foxboro, Mass.* Foxboro Recorder, March 1910, 31 pp.

Kennedy Valve Mfg. Co., *Elmira, N. Y.* Valves for water-works, 30 pp.

J. Geo. Leyner Eng. Wks. Co., *Littletown, Colo.* Bulletin 1016, Drilling costs, 4 pp.

Newton Machine Tool Works, Philadelphia, Pa. Catalogue 46, Bolt threading machines and multiple automatic die heads, 15 pp.

Ohio Brass Co., *Mansfield, O.* Bulletin, April 1910, 24 pp.

UNITED ENGINEERING SOCIETY

A. L. A. Portrait Index, 1906. *Washington, 1906.*

Electric Power Plants. By T. E. Murray. *New York, 1910.* Gift of author.

Engineering Index, 1909. *New York, 1910.*

Iowa Board of Railroad Commissioners. 27th–31st annual reports, 1904–1908. *Des Moines, 1905–1909.* Gift of commissioners.

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New Hampshire Railroad Commission. 65th annual report, 1909. *Manchester, 1910.* Gift of commissioners.

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Ohio Railroad Commission. 1st and 3d reports. *Springfield, 1906, 1908.*
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TRADE CATALOGUES

Schneider & Co., *Paris.* Products and machinery, 19 pp.

———Creusot and Manganese Steel used in Railway Construction, 9 pp.

———Automobile Wheels, 9 pp.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 12th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

032 Assistant draftsman for cement mill repair and reconstruction; salary from $50 to $100 per month, according to usefulness. Apply with full particulars direct to Texas Portland Cement Company, Dallas, Texas, Jno. B. Mayo, Chief Draftsman.

033 An electrical engineer, established in his own wiring contracting business two years, wants young man capable of estimating wiring costs from plans, to invest $5000 in corporation to be formed to take over this business; must take active part, principally in the estimating and commercial part of the work. Acquaintance with architects and engineers desirable.

034 Draftsmen for mill-wright work and building plans; prefer young men not over 25 years of age, with tool-room experience or technical education; two or three years' drafting work. Start at $20 to $25 per week; can give varied experience in laying out new models with the tools for manufacturing and designing special machinery from light automatic machines to heavy hydraulic work. Location, New Jersey.

035 Electrical or mechanical technical graduate of about four years' experience, as inspector and engineer on maintenance and operating. Salary to start, $22.50 per week. Location, New York.

036 Man of good mechanical knowledge wanted, technical graduate preferred, to take charge of price setting in one of the largest machine shops in the eastern states. Excellent opportunity for the right man.

037 Instructor in mechanical and architectural drawing, Tuesday and Thursday evenings, October to May. Drafting room practice and some experience in teaching necessary. Location one hour from Manhattan.

038 Man thoroughly acquainted with modern machine tools and machine shop practice for position in works office of factory; salary and responsibilities depend upon ability. Would probably be called first to look over the machine and tool equipment, determine whether they were the best obtainable for the work to be performed, whether saving could be effected by discarding some of present machines and purchasing others, and determine best methods of handling work in the shop.

MEN AVAILABLE

77 Technical graduate experienced in the design and construction of power plants, industrial plants and mill buildings, wants position which will not confine him to drafting board or office, while not objecting to some office work or drawing.

78 Eastern member, nearly 25 years' experience as civil and mechanical engineer in designing, construction, selling, installation and operating departments of modern power equipment and manufacturing plants; wide personal acquaintance United States, Canada, Great Britain and the continent; successful in dealing with U. S. and foreign government engineer departments, municipal and other public works; familiar with modern office, shop organization and costs; drafting specifications and contracts; good correspondent and executive; active, energetic and resourceful. At present engaged but open for consideration of still larger activities.

79 Superintendent and engineer desires engagement, 18 years' experience designing, estimating and selling special machinery, shop management, systematizing. At present shop manager of large concern; member A. S. M. E.

80 Associate 18 years experience in designing and building automatic machinery, established system for this class of work; 39 years of age. Desires position as superintendent or assistant manager. At present employed.

81 Experienced sales manager or representative desires engagement; preferably with manufacturer of water-tube boiler or other power plant apparatus. Age 32. Extensive experience in designing and selling. Widely acquainted. Location in East or South preferred. Exceptional references.

82 Member wants position as general superintendent or works manager; age 35; practical mechanic, technical education, good hustler and organizer, with experience including heaviest class of machinery.

83 Member, technical graduate with 13 years successful experience as designer, engineer of tests, mechanical engineer in charge and superintendent of engine works, would consider position with either firm of consulting engineers or instructor in machine design and construction. Highly recommended. At present employed.

84 Member, desires position as mechanical engineer for large manufacturing company; about 25 years experience in general mechanical engineering. Salary, $4500 per year. First class reference.

85 Energetic engineer, technical school graduate; 20 years practical experience in the engineering of large up-to-date industry; automatic machine design and construction; building, and power plant design and construction; all complicated engineering problems involved in textile work; operation of large machine shop engaged in building special machinery; mill and power plant maintenance and operation; process investigation and improvement. Works manager or supervising engineer. Best of references.

86 M. E., Stanford University, experienced as instructor in mechanical engineering; also machinist and draftsman. Considerable experience in teaching private classes in descriptive geometry, algebra, trigonometry, calculus and other similar subjects. At present instructor in mechanical engineering connected with experimental engineering laboratory. Desires similar position.

87 Graduate M. E., post graduate work in electrical engineering, class 1897, five years experience in shop and drafting room, eight years testing engineer, mechanical engineer and superintendent. Familiar with marine and power plant machinery and equipment. Inventive and executive ability; organization and shop efficiency. Desires position as superintendent, assistant superintendent, assistant works manager or assistant to consulting engineer; location immaterial.

88 Junior member, graduate of prominent engineering school of middle west, desires responsible position in charge of work or with consulting engineer. Four years experience in charge of college engineering laboratory, including strength of materials; four years drafting and designing with companies building well known line of steam engines. Salary $2000 per year.

89 Graduate in mechanical engineering B. S. and M. E. Experience cover both mechanical and civil fields, general shop practice, railroad location· general engineering and contracting, including power plant design, construction and operation, sewers, waterworks, etc. Desires responsible position with manufacturing or engineering and contracting concern.

90. Technical graduate, eighteen years experience, power producing machinery, boilers, engines, pumps, air and gas compressors and power plant auxiliaries; application of steam, gas, electric and hydraulic power to machinery, familiar with machinery for mining, quarry and tunnel work; responsible positions in the production, engineering and sales departments. At liberty about July 1st. Would prefer company where permanency and advancement are possible. Eastern location preferred.

91 Junior member, executive ability, desires responsible charge of engineering work in New York or vicinity of Orange, N. J. Technical education, chief draftsman four years, shop foreman one year. Age 32. Salary $1500.

92 Member, over twenty years experience, design, superintendence and management in shop and field, desires position, preferably near Philadelphia.

93 Associate, graduate mechanical engineer, fourteen years experience in general engineering work, machine shop, testing power plant design, construction and operation. Five years electric railway work, involving civil, mechanical and electrical engineering; good executive ability, experience in office methods, correspondence, etc. Wishes executive position involving responsibility. Salary $2500.

94 Junior, technical graduate, at present engineer of brass mill; experience laying out and building new plants; construction and design brass and copper mill machinery, furnaces, etc; design and operation steam, high pressure hydraulic and electric power plants; desires to change to position as mechanical engineer of manufacturing plant.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

AFFLECK, H. Watson (Associate, 1906), Pres., Keystone Engrg. Co., 719–721 Noble St., and *for mail*, 1707 Cayuga St., Philadelphia, Pa.

ALLEN, John Robins (1894; 1903), Cons. Engr. and Dir. Dept. of Engrg. Robert College, Constantinople, Turkey.

ANDERSON, Emanuel (Associate, 1907), 5692 Ridge Ave., Chicago, Ill.

APPLETON, Thomas (1893), Supt. of Constr., U. S. Pub. Bldgs., East St. Louis, Ill.

BAEHR, William Alfred (1903), Cons. Engr., Peoples Gas Bldg., Chicago, Ill.

BAKER, George Otis (1906), Cons. and Supervising Engr., 35 Wall St., and *for mail*, 570 W. 183d St., New York, N. Y.

BAKER, William E. (1902), W. E. Baker & Co., 105 W. 40th St., New York, N. Y.

BARNES, William O. (1908), Mech. Engr., Iver Johnson Arms & Cycle Wks., and *for mail*, 110 Blossom St., Fitchburg, Mass.

BAUSH, George Henry (1905), 480 Northampton St., Holyoke, Mass.

BEECHER, J. F. (Associate, 1908), Checker, M.E.Dept., Pa. Steel Co., and *for mail*, 326 North St., Harrisburg, Pa.

BERLINER, Richard W. (Junior, 1903), V. J. Hedden & Sons Co., Bldrs., Metropolitan Life Tower, and *for mail*, 608 Riverside Drive, New York, N. Y.

BITTERLICH, Walter J. (Junior, 1906), Ch. Draftsman, Hood Rubber Co., and *for mail*, 9 Irving St., Watertown, Mass.

BIXBY, Col. William H. (1888), Life Member; U. S. Engr., 508 Colorado Bldg., Washington, D. C.

BORNHOLT, Oscar Charles (1904; 1909), John R. Keim Mills, Buffalo, N. Y.

BRADSHAW, Grant D. (Junior, 1904), Asst. Steam Engr., Cambria Steel Co., Johnstown, Pa.

BRENNER, Wm. H. (1897), Managing Dir., Zemma Wks., Ltd., Isogo Mura, Yokohama, Japan, and Mgr., British Columbia Mfg. Co., Ltd., P. O. Box 154, New Westminster, B. C., Canada.

BROOKS, Louis C. (Junior, 1901), 167 Furman St., Schenectady, N. Y.

BRUFF, Charles E. (1908), Chino Copper Co., Santa Rita, New Mexico.

BUKER, Henry (1907), Western Rep., Brown & Sharpe Mfg. Co., 626–630 Washington Blvd., Chicago, Ill.

BURGESS, Edward W. (Junior, 1908), J. I. Case Threshing Mch. Co., and *for mail*, 1216 Main St., Racine, Wis.

CHISHOLM, John James (Associate, 1904), Supt. of Power, Westinghouse Electric & Mfg. Co., East Pittsburg, Pa.

CHRISTENSEN, Chas. C. (1890), Estimating Engr., Allis-Chalmers Co., and *for mail*, 2910 Logan Blvd., Chicago, Ill.

COLBURN, George L. (Associate, 1903), Prin., Mech. Dept., New Bedford Textile Sch., New Bedford, and *for mail*, 56 Rawson Road, Norfolk Downs, Mass.

COLE, George Wm. (Junior, 1907), Mech. Engr., Great Kills, N. Y.

COLWELL, Augustus W. (1880), 290 E. 17th Ave., Columbus, O.

CONLEE, George D. (Junior, 1906), Supt., Binghamton Gas Wks., 40 Chenango St., and *for mail*, 106 Henry St., Binghamton, N. Y.

COWLES, William Barnum (1881), V. P. and Treas., Long Arm System Co., Lakeside Ave. and E. 38th St., and 11312 Euclid Ave., Cleveland, O.

CROFOOT, George Emerson (Junior, 1907), Instr. in Mech. Engrg., Univ. of Pa., Philadelphia, Pa., and *for mail*, Painesville, O.

DAVIS, A. C. (1909), Am. Mfg. Concern, Jamestown, N. Y.

DAVIS, Chester B. (1890), Rm. 1601, 55 Liberty St., New York, N. Y.

DEACON, Ralph Woolman (Associate, 1907), Asst. Supt., U. S. Metals Refining Co., Chrome, and 120 W. Jersey St., Elizabeth, N. J.

DEAN, Edmund Willard (1905), Mech. Engr., United Printing Mchy. Co., Jamaica Plain, Boston, Mass.

DEARBORN, Wm. Langdon (Junior, 1892), Secy. and Treas., Eastwick Engrg. Co., Ltd., 82 Beaver St., New York, N. Y.

DE LEEUW, Adolph L. (1901), Mech. Engr., Cincinnati Milling Mch. Co., and *for mail*, 308 McGregor Ave., Mt. Auburn, Cincinnati, O.

DENISON, Charles S. (1909), Prof. Stereotomy, Mechanism and Drawing Univ. of Mich., and *for mail*, 412 E. Huron St., Ann Arbor, Mich.

DULL, Raymond Wm. (1908), Ch. Engr. and Supt., Stephens-Adamson Mfg. Co., and *for mail*, 395 Garfield Ave., Aurora, Ill.

DUNN, Harry A. (Junior, 1907), 552 E. 25th St., Paterson, N. J.

EILERS, Karl Emerich (1890; 1904), Am. Smelting & Refining Co., 165 Broadway, New York, and *for mail*, Sea Cliff, L. I., N. Y.

EYERMANN, Peter (1908), Engr. of Constr., Witkowitz Steel Wks., Witkowitz, Austria.

FAILE, E. Hall (Junior, 1907), Cons. Engr., 1 Madison Ave., and 610 W. 116th St., New York, N. Y.

FRANKENBERG, Geo. T. (Associate, 1907), Mech. Engr., Ralston Steel Car Co., and *for mail*, R. F. D. 5, Sta. A, Columbus, O.

FREEMAN, Perry John (Junior, 1908), Instr. Mech. Engrg., Univ. of Pa., Philadelphia, Pa., and *for mail*, Lilly Chapel, O.

GIBSON, Arthur (1892), Supt., Seward Peninsula Power Co., and *for mail*, P. O. Box 200, Nome, Alaska.

GILMAN, Francis L. (1908), Genl. Mgr., Missouri & Kansas Telephone Co., and *for mail*, 3422 Harrison St., Kansas City, Mo.

GOWIE, William (1905), P. O. Box 175, Kittanning, Pa.

HALL, Morris A. (1905; Associate, 1906), 814 Majestic Bldg., Detroit, Mich.

HART, Rogers Bonnell (Associate, 1907), 363 W. 57th St., New York, N. Y.

HASSAN, R. D. (1903), 1211 Fifth Ave., Spokane, Wash.

HAYWARD, Sterling F. (1903), Treas. and Genl. Mgr., Connelly Ir. Sponge & Gov. Co., 127 Duane St., New York, and 64 Locust Hill, Yonkers, N. Y.

HENES, Harry W. (Junior, 1909), A. Bolter's Sons, Structural Steel, 84 LaSalle St., and *for mail*, 557 Barry Ave., Chicago, Ill.

HILL, Robert J. (Associate, 1904), 5027 Madison Ave., Chicago, and 816 Sheridan Rd., Wilmette, Ill.

HONISS, William Henry (1899), Mech. Engr. and Solicitor of Patents, 60 Prospect St., and 102 Huntington St., Hartford, Conn.

HORNE, Convers Francis (Junior, 1905), Contr. Engr., Sterling Blower & Pipe Mfg. Co., Rm. 1025, 30 Church St., New York, and 145 Lefferts Pl., Brooklyn, N. Y.

JACKSON, F. W. (1909), Dist. Mgr., Harrisburg Fdy. & Mch. Wks., 424 N. Y. Life Bldg., Chicago, Ill.

JETT, Carter C. (Junior, 1902), Genl. Delivery, Saulte Ste. Marie, Ont., Canada.

JOHNSON, F. Amos (1907), 22 Morris St., Jersey City, and 15 S. Prospect St., South Orange, N. J.

JOSLYN, Paul L. (1909), Nordberg Mfg. Co., and *for mail*, 198 Junean Ave., Milwaukee, Wis.

LANE, Frederick (1906), Supt., Railway Signal Co. of Canada, Ltd., 609 Canadian Express Bldg., Montreal, and *for mail*, 1 Burton Ave., Westmount, Quebec, Canada.

LAWRENCE, Gerald P. (Junior, 1909), 211 16th Ave., Columbus, O.

LAWRENCE, Howard F. (Junior, 1908), Amer. Ship Windlass Co., and *for mail*, 279 George St., Providence, R. I.

LELAND, Henry Martin (1895), Genl. Mgr., Cadillac Motor Car Co., 1343 Cass Ave., and *for mail*, 2984 Grand Boulevard, W., Detroit, Mich.

LILLIBRIDGE, Ray D. (Associate, 1907), 192 Broadway, and P. O. Box 824, New York, N. Y.

LOCKETT, Kenneth (1904; Associate, 1907), Mech. Engr., Orr & Lockett Hdw. Co., 71-73 Randolph St., Chicago, Ill.

LOCKWOOD, James Fred (1889; 1907), Mgr., Security Elev. Safety Co., 126 W. 18th St., New York, N. Y., and *for mail*, Keansburg, N. J.

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McFARLAND, Walter M. (1883), Vice-President, 1905–1907; Babcock & Wilcox Co., 85 Liberty St., New York, N. Y.

MacARTHUR, Robert, Jr. (Associate, 1904), Supt. M. P., Sargent & Co., and *for mail*, 226 McKinley Ave., New Haven, Conn.

MADDOCK, George F. (1903), H. M. Byllesby & Co., 806 Lewis Bldg., Portland, Ore.

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MEYER, C. Louis (Junior, 1909), Freeborn Engrg. & Constr. Co., 609 Scarritt Bldg., Kansas City, Mo., and 210 S. 36th St., Omaha, Neb.

MOORE, Harold T. (Associate, 1907), Cruse-Kemper Co., Ambler, and *for mail*, 457 Hansberry St., Germantown, Philadelphia, Pa.

MORRISON, Herbert H. (1898; 1904), Mech. Engr., 408 Bd. of Educ. Bldg., St. Louis, Mo.

MOULTHROP, Leslie (Associate, 1891), Receiver, Dwight Slate Mch. Co., New Haven, and *for mail*, Short Beach, Conn.

MUELLER, Otto Nicholas (Junior, 1907), Ch. Engr., Noelke Richards Iron Wks., and *for mail*, 1314 Union St., Indianapolis, Ind.

MUNBY, E. John (1906), Mgr., St. John Mine, Montezuma, Colo., also Baddow Park, Essex, England.

MURPHY, John Z. (1899), Ch. Engr., Chicago Rys. Co., 700 Boatland Bldg., and *for mail*, 3818 Lexington St., Chicago, Ill.

NICKERSON, Ralph R. (Junior, 1907), Geo. F. Blake Mfg. Co., East Cambridge, and *for mail*, Somerville Y. M. C. A., Somerville, Mass.

NOLDE, Frederick (Junior, 1901), Fairview Village, Montgomery Co., Pa.

OLMSTED, George C. (Junior, 1909), Mech. Engr., Crystal Falls, Mich.

PALMER, Cortlandt E. (1895), Cons. Min. Engr., Rm. 1104, 2 Rector St., and 137 E. 19th St., New York, N. Y.

PARSONS, Frederick W. (1889), Supt., Rand Drill Co., and Brookside Park, Tarrytown, and *for mail*, 300 Maple Ave., Elmira, N. Y.

PEARSALL, Gilbert H. (Associate, 1908) Genl. Mgr. of Sales, Jos. T. Ryerson & Son, 30 Church St., New York, N. Y.

PLEASONTON, F. Rodney (Junior, 1908), Penn. Steel Co., Steelton, Pa.

POSSELT, Ejnar (Junior, 1907), Mech. Engr. and Asst. Mgr., St. Louis Portland Cement Wks., and *for mail*, care Geo. Posselt, 3526 Washington Ave., St. Louis, Mo.

PROSSER, Joseph George (1891; 1898), 1301 E. 60th St., Chicago, Ill.

REEVE, Sidney A. (1901), Cons. Engr., 20 Central Ave., Tompkinsville, S. I., N. Y.

RICHARDS, Chas. Dexter (Junior, 1904), Asst. Engr. of Tests, Solvay Process Co., and *for mail*, 332 Canton Ave., Detroit, Mich.

ROTTER, Max (1899), Mech. Engr., Allis-Chalmers Co., and *for mail*, 251 33d St., Milwaukee, Wis.

SAGUE, Samuel Reston (Junior, 1908), Sales Engr., Power House Equip., Strong, Carlisle & Hammond Co., Cleveland, and *for mail*, 47 Vassar St., East Cleveland, O.

SEARLE, Wilbur C. (Junior, 1909), Heald Mch. Co., and *for mail*, 24 Townsend St., Worcester, Mass.

SHAW, Arthur Derwood (Associate, 1905), Sagax Wood Co., ft. Andre St., Locust Pt., Baltimore, Md.

SHIRRELL, David (1890), Am. Loco. Co., and *for mail*, 852 Union St., Schenectady, N. Y.

STACKS, H. Roy (1909), Supt., Geo. V. Cresson Co., 18th and Allegheny Ave., Philadelphia, and *for mail*, Glenside, Pa.

STEELE, Walter D. (1892; 1901), V. P., Benjamin Elec. Mfg. Co., 120–128 S. Sangamon St., Chicago, Ill.

SWEET, Franklin (Junior, 1903), 603 E. Main St., Portland, Ore.

TABOR, Leroy (1909), Supt., Morrow Mfg. Co., and *for mail*, 604 W. Water St., Elmira, N. Y.

THOMPSON, Edward C. (Junior, 1909), Genl. Mgr., Victor Tire Traction Co., 16 State St., Boston, and *for mail*, 96 Geneva Ave., Dorchester, Mass.

TROUTMAN, Howard Ellsworth (Associate, 1906), Asst. Sales Mgr., International Steam Pump Co., 770 Old Colony Bldg., and *for mail*, 4448 Prairie Ave., Chicago. Ill.

WALLACE, Fred A. (Associate, 1896), M. M., Pacific Mills, and *for mail*, 75 Knox St., Lawrence, Mass.

WHEELER, Frank R. (1909), Mgr., C. H. Wheeler Mfg. Co., 825 Marquette Bldg., Chicago, Ill.

WHITE, Herbert J. (1909), Lanston Monotype Mch. Co., Philadelphia, Pa., and 439 Eighth St., Brooklyn, N. Y.

WHITE, Merton G. (Junior, 1906), Mgr., Fitchburg Steam Engine Co., 50 Church St., New York, N. Y.

WHITTEMORE, Herbert L. (Junior, 1903), Watertown Arsenal, Watertown, Mass.

WILLIAMSON, Leroy A. (Associate, 1902), Bd. of Trade Bldg., 131 State St., and *for mail*, Hotel Wadsworth, Kenmore and Newbury Sts., Boston, Mass.

WOODWARD, Robt. S., Jr. (Junior, 1904), Cons. Engr., 5001 Lancaster Ave., Philadelphia, Pa.

YOUNG, E. R. (Junior, 1900), 1712 Jefferson St., Ensley, Ala.

YOUNG, Gilbert, A. (1906), Asst. Prof. Mech. Engrg., Purdue Univ., 409 University Ave., West Lafayette, Ind.

YOUNG, William (1901; 1905; 1906), 339 24th Ave., Milwaukee, Wis.

ZIMMERMANN, Wm. F. (1884), Pittsburg Testing Lab., 325 Water St., Pittsburg, Pa.

NEW MEMBERS

BEST, William John (1910), Treas., Wheeler Condenser & Engrg. Co., and *for mail*, Carteret, N. J.

BONNER, Richard Oliver (Junior, 1910), Supt. of Constr., Factory Bldgs., P. O. Box 152, Rockville Center, L. I., N. Y.

BRADY, Joseph Benjamin (Junior, 1910), Asst. Experimental Engr., Hess-Bright Mfg. Co., 21st and Fairmount Ave., Philadelphia, Pa.

BROWN, Edward W. (1910), V. P. and Genl. Mgr., Sterling Salt Co., 23 Beaver St., New York, N. Y.

BRYANT, William L. (1910), Mgr., Bryant Chucking Grinder Co., Springfield, Vt.

BURCH, Henry Kenyon (1910), Mech. Engr., Miami Copper Co., Miami, Ariz.

BURGESS, Frank (Associate, 1910), Prop. and Genl. Mgr., Boston Gear Wks.' Norfolk Downs, and *for mail*, 78 Beach St., Wollaston, Mass.

CARSON, Whitfield Robert (1910), Constr. Engr., Taylor Iron & Steel Co., High Bridge, N. J.

CHAPMAN, Cloyd Mason (1910), Engr. in Charge, Westinghouse, Church, Kerr & Co., 10 Bridge St., New York, N. Y.

CHAPMAN, Harry Burdett (1910), Mech. Engr., Am. Optical Co., Southbridge, Mass.

CLARK, Frank Henry (1910), Genl. Supt., M. P., Burlington System, C. B. & Q. R.R., and *for mail*, 209 Adams St., Chicago, Ill.

CONE, Hutchinson Ingram (1910), Engr. in Charge, Bureau of Steam Engrg., Navy Dept., Washington, D. C.

COOK, Harry Hall (Junior, 1910), Ch. Engr., Coffin Valve Co., Boston, and *for mail*, 27 Lamartine St., Jamaica Plain, Mass.

COOK, William Henry (Junior, 1910). Am. Loco. Co., Cooke Wks., Paterson, and *for mail*, Hawthorne, N. J.

COOLEY, Erwin Stratton (1910), Mech. Engr., Connecticut Co., and *for mail*, 115 Brownell St., New Haven, Conn.

COSTER, Eric Herbert (1910), Engr., Westinghouse, Church, Kerr & Co., New York, N. Y., and *for mail*, 9 Lawn Ridge Rd., Orange, N. J.

CRESSLER, Alfred David (1910), Pres. and Cons. Engr., Kerr Murray Mfg. Co., Ft. Wayne, Ind.

CRUTE, William Rowzie (Junior, 1910), Asst. M. M., Mathieson Alkali Wks., Saltville, Va.

CUMMINGS, Byron (1910), Supt. Inspc. Dept., Ocean Accident & Guarantee Corp., and *for mail*, 988 Simpson St., New York, N. Y.

DAY, Paul (1909), Treas., Federal Lumber Co., Blaine, Wash.

DOANE, John Appleton (1910), Supt. of Shops, Taylor Iron & Steel Co., High Bridge, N. J.

ELLENBOGEN, Sidney Arthur (Junior, 1910), Manhattan Shirt Co., 207 River St., Paterson, N. J.

ENNIS, Herbert Vrooman (Junior, 1910), Engrg. Dept., Am. Car & Fdy. Co., New York, N. Y., and *for mail*, 543 Broadway, Paterson, N. J.

ERNSBERGER, Millard Clayton (1910), Prof. Mech. Engrg., Univ. of Rochester, Rochester, N. Y.

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FROST, Harwood (1910), Secy., Engrg. News Pub. Co., 220 Broadway, New York, N. Y.

FULLER, James Wheeler, Jr., (1910), Genl. Mgr., Lehigh Car, Wheel & Axle Wks., and *for mail*, Bridge St. and Howertown Rd., Catasauqua, Pa.

GALLUP, David Lamprey (1910), Asst. Prof. Gas Engrg., Worcester Poly. Inst., Worcester, Mass.

GANZ, Albert Frederick (1910), Prof. Elec. Engrg., Stevens Inst., of Tech., Hoboken, N. J

GAST, George Fred (Junior, 1910), Ch. Draftsman and Constr. Engr. with Walter Kidde, 140 Cedar St., New York, N. Y., and *for mail*, 122 W. 34th St., Bayonne, N. J.

GREEN, John Stevenson (Junior, 1909), 391 Pine St., Providence, R. I.

HALL, Dwight Kimball (Junior, 1910), Asst. Supt., Frank A. Hall Bedstead Factory, Goshen, N. Y.

HARTLEY, Harry Dwight (Junior, 1910), Pioneer Pole & Shaft Co., Piqua, O.

HERSCHEL, Winslow Hobart (1910), care Clemens Herschel, 2 Wall St., New York, N. Y.

HEY, Harry Albert (Junior, 1910), Assoc. Editor, Am.Soc.M.E., 29 W. 39th St., New York, N. Y.

HODGSON, Alec Wilberforce (1910), Asst. Engr., Hudson & Manhattan R. R. Co., New York, N. Y., and *for mail* 190 Belmont Ave., Jersey City, N. J.

HOLMES, Urban Tigner (1910), Designing Engr., Bureau of Steam Engrg., Navy Dept., and *for mail*, 1705 21st St., N. W., Washington, D. C.

HUSTED, Clifford Mackay (Junior, 1910), Asst. Supt., Husted Milling Co., and *for mail*, 292 North St., Buffalo, N. Y.

KEABLES, Austin Dow (Junior, 1910), Mech. Engr. with John A. Stevens, Cons. Engr., and *for mail*, 14 Hoyt Ave., Lowell, Mass.

KINGSLEY, Frank (1910), Asst. Engr., Westinghouse, Church, Kerr & Co., New York, and *for mail*, 94 Neptune Park, New Rochelle, N. Y.

LANGE, Heinrich Bartels (Junior, 1910), Estimating and Genl. Engrg. Depts., C. W. Hunt Co., West New Brighton, N. Y.

LEBRECHT, A. (1910), Ch. Engr., Gas and Oil Eng. Dept., De La Vergne Mch. Co., and *for mail*, 1879 Madison Ave., New York, N. Y.

LESTER, Clarence R. (1910), Inspr., Sales Dept., Packard Motor Car Co., and *for mail*, Plaza Hotel, Detroit, Mich.

LONDON, William James Albert (1910), Ch. Engr., Terry Steam Turbine Co., Hartford, Conn.

McCREERY, James Harold (Junior, 1910), Rm. 802, Atlantic Bldg., 49 Wall St., New York, N. Y., and *for mail*, Truell Inn, Plainfield, N. J.

McLEOD, Adolphus A. (1910), Engr., Supt., Florida Phosphate Mining Corp., and *for mail*, Bartow, Fla.

McWEENEY, Laurence Riley (Junior, 1909), Asst. Supt., Russell, Burdsall & Ward Bolt and Nut Co., Port Chester, N. Y.

MAROT, William Griscom (1910), Secy. and Treas., Syracuse Gas Engine Co., and *for mail*, 1809 Park St., Syracuse, N. Y.

METCALF, Frank Hamilton (1910), Asst. Mgr., Farr Alpaca Co., Holyoke, Mass.

MILLER, John Fisher Garr (1910), Engrg. Salesman and Mgr., St. Louis Office, Am. Blower Co., Lincoln Title Guaranty Trust Bldg., St. Louis, Mo.

MOODY, Lewis F. (1910), Asst. Prof. Mech. Engrg., Rensselaer Poly. Inst., and *for mail*. 7 Hawthorne Ave., Troy, N. Y.

MUDGE, Samuel Tenney (Junior, 1910), Instr., Univ. of Mich., and *for mail*, 508 Elm St., Ann Arbor, Mich.

PAINTER, John G. (Junior, 1910), Asst. M. M., Philadelphia Watch Case Co., Riverside, and *for mail*, 941 S. Fourth St., Camden, N. J.

PARR, Harry Lilienthal (1910), Instr. Mech. Engr., Columbia Univ., New York, N. Y.

PETERSON, Carl H. (1910), Tech. Rep., Baldwin Loco. Wks. and Standard Steel Wks. Co., 623 Rwy. Exch., Chicago, Ill.

REDFIELD, Snowden B. (1910), Assoc. Editor, American Machinist, 505 Pearl St., and 216 W. 102nd St., New York, N. Y.

ROESLER, Dr Rudolph (Junior, 1910), Cons. Engr., Ladenburg, Thalmann & Co., 25 Broad St., New York, N. Y.

SANFORD, George Ruggles (1910), Chem. Engr. and Coke Oven Supt., Solvay Process Co., Syracuse, N. Y.

SCHLACKS, W. J. (1909), McCord & Co., Peoples Gas Bldg., Chicago, Ill.

SCHLATTER, Rudolph (1910), Asst. Engr., Steam Turbine Dept., Allis-Chalmers Co., and *for mail*, 596 Jackson St., Milwaukee, Wis.

SCOLLAN, John Joseph (1910), 43 King St. W., Toronto, Ont., Canada.

SEARS, Frank M. (Associate, 1910), Treas. and Mgr., Holyoke Steam Boiler Wks., Holyoke, Mass.

SESSIONS, Frank Lord (1910), Ch. Engr., Mining Mchy. Dept., Jeffrey Mfg. Co., Columbus, O.

SHALLCROSS, Watson Comly (1910), Asst. Mgr., Caustic Soda Dept., Solvay Process Co., Syracuse, N. Y.

SIEVERS, Ernest John Joseph (Junior, 1910), Engr., Automatic Sprinkler Co., New York, N. Y., and *for mail*, 65 Willow Ave., Hoboken, N. J.

SLOANE, Charles O'Conor (Junior, 1910), Niles-Bement-Pond Co., New York, N. Y., and *for mail*, 55 Montrose Ave., South Orange, N. J.

SPERRY, Elmer Ambrose (1910), Cons. Engr., 40 Wall St., New York, N. Y.

STOCKWELL, Rupert Kennedy (Junior, 1910), Constr. Engr., U. S. Smelting Co., 920 Newhouse Bldg., Salt Lake City, Utah.

SUMMER, Eliot (1910), M. M., Baltimore Division, Pa. R. R., Baltimore, Md.

SWARTWOUT, Everett W. (Junior, 1910), Nordberg Mfg. Co., 42 Broadway, New York, and *for mail*, Scarsdale, N. Y.

TENNEY, Theodore Smith (1910), Nygren, Tenney & Ohmes, Cons. Engrg., 87 Nassau St., New York, N. Y.

THOMPSON, O. C. (Associate, 1910), Wks. Mgr., Natl. Wire Bound Box Co., and *for mail*, Y. M. C. A., South Bend, Ind.

THORN, Charles Norman (Associate, 1910), Asst. Mgr., Mchy. Dept., Manning, Maxwell & Moore, Inc., 85 Liberty St., New York, N. Y.

WEBSTER, Lawrence Burns (Junior, 1910), 15329 Center Ave., Harvey, Ill.

WESTCOTT, Valorus Stukely (1910), Mech. Supt., J. & P. Coats, Ltd., and *for mail*, 644 Main St., Pawtucket, R. I.

WHITCOMB, Lawrence (Associate, 1910), Treas. and Genl. Mgr., Natl. Brake & Clutch Co., 16 State St., Boston, Mass.

WHITESIDE, Walter Hunter (1910), Pres., Allis-Chalmers Co., Milwaukee, Wis.

WINSOR, Paul (1910), Ch. Engr., M. P. and Rolling Stock, Boston Elevated Ry. Co., 101 Milk St., Boston, Mass.

WOODMAN, Forrest E. (Junior, 1910), Junior Engr., Tech. Branch, U. S. Geolog. Survey, 40th and Butler Sts., Pittsburg, Pa.

ZACHERT, Arthur Robert (Junior, 1910), Shop Draftsman, Babcock & Wilcox Co., and *for mail*, P. O. Box 123, Bayonne, N. J.

ZOWSKI-ZWIERZCHOWSKI, S. J. (1910), Asst. Prof. Mech. Engrg., Univ. of Mich., and *for mail*, 1523 S. University Ave., Ann Arbor, Mich.

PROMOTIONS

BISHOP, Frank (1907; 1910), Mech. Engr., Singer Mfg. Co., Factory No. 3, and *for mail*, 1241 Michigan Ave., South Bend, Ind.

BURSLEY, Joseph Aldrich (1906; 1910), Asst. Prof. Mech. Engrg., Univ. of Mich. ,and *for mail*, 815 Forest Ave., Ann Harbor, Mich.

DAVIS, Thomas B. (1907; 1909), Ch. Engr., Cleveland Crane & Engrg. Co., Wickliffe, and *for mail*, 65 Stanwood Rd., East Cleveland, O.

DIETZ, Carl F. (1903; 1910), Cons. Engr., Dietz & Keedy, 6 Beacon St., Boston, and *for mail*, 306 Main St., Melrose, Mass.

KENNEDY, Frank Lowell (1903; 1910), Asst. Prof. Drawing and Mch. Design, Harvard Univ., and *for mail*, 43 Appleton St., Cambridge, Mass.

KING, Roy Stevenson (1904; 1910), Genl. Supt., Hall-Cronan Co., 1111-1113 U. S. Bldg., and *for mail*, 43 Wroe Ave., Dayton, O.

MARSHALL, Stewart McCulloch (1907; 1910), Asst. Ch. Engr., Cambria Steel Co., and *for mail*, 120 Tioga St., Johnstown, Pa.

SATTERFIELD, Howard E. (1908; 1910), Prof. Mech. Engrg., N. C. College of Agri. and Mech Arts, West Raleigh, N. C.
YOUNG, Chas. D. (1902; 1910), Asst. Engr. M. P., Pa. Lines West of Pittsburg, Rm. 1002, Union Sta. Bldg., Pittsburg, Pa.

DEATHS

FERRY, Charles H., May 2, 1910
FOSTER, Charles F., May 8, 1910
KERR, Walter C., May 8, 1910
McKAY, John Edwards, May 12, 1910
SAVERY, Thomas H., April 5, 1910

GAS POWER SECTION

CHANGES OF ADDRESS

BAEHR, William Alfred (1908), Mem. Am. Soc. M. E.
CONLEE, George D. (1908), Mem. Am. Soc. M. E.
DAVIDSON, T. C. (Affiliate, 1909), Gas Eng. Erector, 339 Pine Ave., and *for mail*, 429 27th Ave., Milwaukee, Wis.
FISCHER, Wm. Francis (Affiliate, 1909), Draftsman, Engrg. Dept., N. Y. Edison Co., 55 Duane St., and *for mail*, 987 Summit Ave., New York, N. Y.
HOPKINS, George Jay (Affiliate, 1909), Duntley Mfg. Co., Sycamore, Ill.
LAWRENCE, Gerald P. (1909), Mem. Am. Soc. M. E.
de MITKIEWICZ, R. S. (Affiliate, 1908), Power Sales Engr., Alden Sampson Mfg. Co., 102 W. 46th St., and *for mail*, 117 W. 58th St., New York, N. Y.
MORRISON, Herbert H. (1908), Mem. Am. Soc. M. E.
REEVE, Sidney A. (1908), Mem. Am. Soc. M. E.
THOMAS, Richard H. (Affiliate, 1909), 81-83 Centre St., New York, N. Y.
YOUNG, Gilbert A (1908), Mem. Am. Soc. M. E.

NEW MEMBERS

BLEYER, Chas. F. (1910), Mem. Am. Soc. M. E.
BLOEMEKE, Rudolph B. (1910), Mem. Am. Soc. M. E.
CASTLE, Samuel Northrup (1910), Mem. Am. Soc. M. E.
CORLETTE, Glen H. (Affiliate, 1910), 566 Calle Moreno, Buenos Aires, Argentine Republic, South America.
DITTO, Charles Carlton (Affiliate, 1910), Ch. Engr., Bartlesville Light & Water Co., and *for mail*, Lock Box 1056, Bartlesville, Okla.
FLINT, William P. (1910), Mem. Am. Soc. M. E.
FRARY, Hobart D. (Affiliate, 1910), Engr. and Magnetic Observer, Magnetic Survey Yatch Carnegie, and *for mail*, care Dept. of Terrestrial Magnetism, The Ontario, Washington, D. C.
FROST, Frank S. (Affiliate, 1910), Head Draftsman, Gas Eng. Dept., Baker Mfg. Co., and *for mail*, Evansville, Wis.
GRIFFITH, Leigh Merriam (Affiliate, 1910), Cons. Mch. Designer, 128 N. Main St., Los Angeles, Cal.
JEWETT, Arthur C. (1910), Mem. Am. Soc. M. E.
JOHNSON, Louis L. (1910), Mem. Am. Soc. M. E.
JOHNSTON, John Parry (1910), Mem. Am. Soc. M. E.
KAVANAUGH, Wm. H. (1910), Mem. Am. Soc. M. E.
MERRITT, John Sniffin (Affiliate, 1910), Fairbanks Co., cor. Broome and Lafayette Sts., New York, and *for mail*, 65 Prospect Ave., Mamaroneck, N. Y
MILLER, Frank Louis (1910), Mem. Am. Soc. M. E.
RANDALL, Dwight T. (1910), Mem. Am. Soc. M. E.
THOMAS, Fred H. (1910), Mem. Am. Soc. M. E.

STUDENT BRANCHES

CHANGES OF ADDRESS

ALLEN, Chas. C. (Student, 1909), 1727 Church St., Galveston, Tex
BADEAU, Ralph P. (Student, 1909), 416 Linden Ave., Elizabeth, N. J
BAUGHMAN, I. N. (Student, 1909), Box 827, Marseilles, Ill.
BESS, Earl (Student, 1910), Bess Laundry Mchy. Co., Hamilton, O.
CARNAHAN, O. A. (Student, 1909), Bolivar, N. Y.
CHU, P. F. (Student, 1909), 319 Dryden Rd., Ithaca, N. Y.
COLEMAN, Wm. F. (Student, 1909), 4300 Park Ave., Champaign, Ill.
COOK, G. C. (Student, 1909), Millington, N. J.
COYLE, J. F. (Student, 1909), Matheson Motor Car Co., Wilkes-Barre, Pa.
DUNSHEATH, L. M. (Student, 1909), 127 Galena Blvd., Aurora, Ill.
GRENOBLE, H. S. (Student, 1909), 1380 Summit St., Columbus, O.
GROSSBERG, Arthur S. (Student, 1909), 407 E. Tenth St., Topeka, Kan.
HATMAN, Julius G. (Student, 1910), 749 Van Buren St., Milwaukee, Wis.
HEILMAN, H. C. (Student, 1909), 1511 N. 20th St., Philadelphia, Pa.
LAWRENCE, J. H. (Student, 1909), 128 W. 91st St., New York, N. Y.
LAY, Robert P. (Student, 1910), 203 Barrett St., Syracuse, N. Y.
LORD, J. Willard (Student, 1910), R. F. D. 43, Norwalk, Conn.
MERRIAM, Frank E. (Student, 1910), 80 Madison St., Skowhegan, Mo.
MESTON, A. F. (Student, 1909), 816 Ross Ave., Wilkinsburg, Pa.
QUICK, Ray Lewis (Student, 1909), 141 Washington St., Hartford, Conn.
SIMONTON, P. D. (Student, 1910), R. F. D., Yarmouth, Me.
STROUSE, A. F. (Student, 1910), 1317 Dennison Ave., Pittsburg, Pa.
VAUGHAN, L. L. (Student, 1910), Franklin, Va.
WATROUS, R. W. (Student, 1910), 559 Ashland Ave., St. Paul, Minn.
WHITE, J. Frank (Student, 1910), Huntingdon, Pa.
WOOD, S. G. (Student, 1909), Box 145, Franklin Park, Ill.

NEW MEMBERS

CORNELL UNIVERSITY

FARRINGTON, T. H. (Student, 1910), 777 Stewart Ave., Ithaca, N. Y.
FRIED, J. A. (Student, 1910), 105 Highland Pl., Ithaca, N. Y.
SOUTHWICK, Charles (Student, 1910), 222 University Ave., Ithaca, N. Y.
THOMAS, F. (Student, 1910), Sheldon Court, Ithaca, N. Y.
WINSHIP, R. (Student, 1910), 458 Cascadilla Pl., Ithaca, N. Y.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

COPELAND, S. B. (Student, 1910), 234 Newbury St., Boston, Mass.
MacPHERSON, R. G. (Student, 1910), 30 Pine St., South Framingham, Mass.

STEVENS INSTITUTE OF TECHNOLOGY

CUTTER, J. D. (Student, 1910), 1208 Pacific St., Brooklyn, N. Y.
SCHLEGEL, C. A. (Student, 1910), 507 River St., Hoboken, N. J.

UNIVERSITY OF ARKANSAS

BOLES, C. B. (Student, 1910), 216 N. E. St., Fayetteville, Ark.
DICKENSON, B. F. (Student, 1910), 1608 Battery St., Little Rock, Ark.

UNIVERSITY OF ILLINOIS

COBB, C. C. (Student, 1910), 909 W. Green St., Urbana, Ill.
HOMS, J. M. (Student, 1910), 1012 W. Oregon St., Urbana, Ill.

UNIVERSITY OF MAINE

CHAPMAN, G. B. (Student, 1910), Phi Eta Kappa House, Orono, Me.
PINKHAM, C. J. (Student, 1910), Oak Hall, Orono, Me.

UNIVERSITY OF NEBRASKA

STRIETER, M. E. (Student, 1910), 104 Oneida Ave., Davenport, Ia.
WOHLENBERG, W. J. (Student, 1910), 844 Seventh St., Lincoln, Neb.

UNIVERSITY OF WISCONSIN

SCHLECK, Walter H. (Student, 1910), Box 530, South Milwaukee, Wis.

COMING MEETINGS

July–August

Advance notices of annual and semi-annual meetings of engineering societies are regularly published under this heading and secretaries or members of societies whose meetings are of interest to engineers are invited to send such notices for publication. They should be in the editor's hands by the 15th of the month preceding the meeting. When the titles of papers read at monthly meetings are furnished they will also be published.

AMERICAN EXPOSITION IN BERLIN

June 1–Aug. 31. American Manager, Max Vieweger, 50 Church St., New York.

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS

June 30–July 1, semi-annual meeting, St. Louis, Mo. Secy., W. M. Mackay, P. O. Box 1818, New York.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

July 26–29, meeting with Institution of Mechanical Engineers, in Birmingham and London, England. Secy., Calvin W. Rice, 29 W. 39th St., New York.

AMERICAN SOCIETY FOR TESTING MATERIALS

June 28–July 2, annual meeting, Atlantic City, N. J. Papers: Untruly and Unevenly Chilled Car Wheels, D. T. West, Mem.Am.Soc.M.E.; Aluminates: Their Properties and Possibilities in Cement Manufacture, Henry S. Spackman, Mem.Am.Soc.M.E.; Fuel Investigation, U. S. Geological Survey, Progress during the year ending June 30, 1910, J. A. Holmes, Mem.Am.Soc.M.E. Secy., Edgar Marburg, University of Pennsylvania, Philadelphia.

CANADIAN ELECTRICAL ASSOCIATION

July 6–8, annual convention, Royal Muskoka, Lake Rosseau. Secy., T. S. Young, Confederation Life Bldg., Toronto, Ont.

INTERNATIONAL ACETYLENE ASSOCIATION

August 3–5, annual meeting, Congress Hotel Annex, Chicago, Ill. Secy., A. Cressy Morrison, 157 Michigan Ave.

INTERNATIONAL EXPOSITION OF CLAY, CEMENT AND LIME INDUSTRIES

June 1–July 18, second annual convention, Berlin. Under the auspices of German Association for the Clay, Cement and Lime Industries, Dreyse-Str. 4, Berlin, Germany.

INTERNATIONAL RAILWAY CONGRESS

July 4-16, Berne, Switzerland. Executive Committee, rue de Louvain, 11, Brussels.

INTERNATIONAL RAILROAD BLACKSMITHS ASSOCIATION

August 17-19, annual convention, Detroit, Mich. Secy., A. L. Woodworth, Lima, O.

NATIONAL ASSOCIATION OF MASTER SHEET METAL WORKERS

August 10–13, Lulu Temple, Broad and Spring Garden Sts., Philadelphia, Pa. Secy., Otto Goebel, 523 Columbus Ave., Syracuse, N. Y.

NATIONAL ELECTRIC CONTRACTORS ASSOCIATION

July 20, annual meeting, Atlantic City, N. J. Secy., W. H. Morton, Martin Bldg., Utica, N. Y.

OHIO ELECTRIC LIGHT ASSOCIATION

July 26–28, annual convention, Cedar Point, O. Secy., P. L. Gaskill, Greenville, O.

TRAVELING ENGINEERS ASSOCIATION

August 16–19, annual convention, Clifton Hotel, Niagara Falls, Canada. Secy., W. O. Thompson, care of N. Y. C. Car Shops, East Buffalo, N. Y.

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Members of the Council for 1910

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Terms expire at Annual Meeting of 1910

H. L. Gantt .... New York
I. E. Moultrop .... Boston, Mass.
W. J. Sando .... Milwaukee, Wis.

Terms expire at Annual Meeting of 1911

J. Sellers Bancroft .... Philadelphia, Pa.
James Hartness .... Springfield, Vt.
H. G. Reist .... Schenectady, N. Y.

Terms expire at Annual Meeting of 1912

TREASURER

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MEETINGS

Willis E. Hall (5), *Chairman*
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MEMBERSHIP

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PUBLICATION

D. S. Jacobus (1), *Chairman*
Fred R. Low (3)
H. F. J. Porter (2)
Geo. I. Rockwood (4)
Geo. M. Basford (5)

RESEARCH

W. F. M. Goss (4), *Chairman*
R. H. Rice (2).
R. C. Carpenter (1)
Ralph D. Mershon (3)
Jas. Christie (5)

Note—Numbers in parentheses indicate number of years the member has yet to serve

SPECIAL COMMITTEES

1910

On a Standard Tonnage Basis for Refrigeration

D. S. Jacobus — G. T. Voorhees
A. P. Trautwein — Philip De C. Ball
E. F. Miller

On Society History

John E. Sweet — H. H. Suplee
Chas. Wallace Hunt

On Constitution and By-Laws

Chas. Wallace Hunt, *Chairman* — F. R. Hutton
G. M. Basford — D. S. Jacobus
Jesse M. Smith

On Conservation of Natural Resources

Geo. F. Swain, *Chairman* — L. D. Burlingame
Charles Whiting Baker — M. L. Holman
Calvin W. Rice

On International Standards for Pipe Threads

E. M. Herr, *Chairman* — Geo. M. Bond
William J. Baldwin — Stanley G. Flagg, Jr.

On Standards for Involute Gears

Wilfred Lewis, *Chairman* — E. R. Fellows
Hugo Bilgram — C. R. Gabriel
Gaetano Lanza

On Power Tests

D. S. Jacobus, *Chairman* — L. P. Breckenridge — Edward F. Miller
Edward T. Adams — William Kent — Arthur West
George H. Barrus — Charles E. Lucke — Albert C. Wood

On Student Branches

F. R. Hutton, Honorary Secretary

On Arrangements for Joint Meeting in England

Ambrose Swasey, *Chairman* — Chas. Whiting Baker, *Vice-Chairman*
Geo. M. Brill — John R. Freeman
W. F. M. Goss

Members Ex Officio

George Westinghouse, President — F. R. Hutton, Honorary Secretary
William H. Wiley, Treasurer — Calvin W. Rice, Secretary
Willis E. Hall, Chairman Meetings Committee

SOCIETY REPRESENTATIVES

1910

On John Fritz Medal

Ambrose Swasey (1)
F. R. Hutton (2)
Chas. Wallace Hunt (3)
Henry R. Towne (4)

On Board of Trustees United Engineering Societies Building

F. R. Hutton (1)
Fred J. Miller (2)
Jesse M. Smith (3)

On Library Conference Committee

J. W. Lieb, Jr., Chairman of the Library Committee, Am.Soc.M.E.

On National Fire Protection Association

John R. Freeman
Ira H. Woolson

On Joint Committee on Engineering Education

Alex. C. Humphreys
F. W. Taylor

On Advisory Board National Conservation Commission

Geo. F. Swain
John R. Freeman
Chas. T. Main

On Council of American Association for the Advancement of Science

Alex. C. Humphreys
Fred J. Miller

Note—Numbers in parentheses indicate number of years the member has yet to serve

OFFICERS OF THE GAS POWER SECTION

1910

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J. R. Bibbins	Geo. A. Orrok

GAS POWER EXECUTIVE COMMITTEE

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GAS POWER INSTALLATIONS COMMITTEE

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Note—Numbers in parentheses indicate number of years the member has yet to serve

MEETINGS OF THE SOCIETY

THE MEETINGS COMMITTEE

Willis E. Hall (5), *Chairman* — L. R. Pomeroy (2)
Wm. H. Bryan (1) — Chas. E. Lucke (3)
H. deB. Parsons (4)

Meetings of the Society in Boston

Ira N. Hollis, *Chairman* — I. E. Moultrop, *Secretary*
Edward F. Miller — J. H. Libbey

Meetings of the Society in St. Louis

Wm. H. Bryan, *Chairman* — Ernest L. Ohle, *Secretary*
R. H. Tait, *Vice-Chairman* — Fred E. Bausch
M. L. Holman

OFFICERS OF STUDENT BRANCHES

Institution	Branch authorized by Council	Honorary Chairman	President	Corresponding Secretary
	1908			
Stevens Inst. of Tech., Hoboken, N. J.	December 4	Alex. C. Humphreys	H. H. Haynes	R. H. Upson
Cornell University, Ithaca, N. Y.	December 4	R. C. Carpenter	C. C. Allen	C.F. Hirschfeld
	1909			
Armour Inst. of Tech., Chicago, Ill.	March 9	G. F. Gebhardt	F. E. Wernick	W. E. Thomas
Leland Stanford Jr. University, Palo Alto, Cal.	March 9	W. F. Durand	A F. Meston	J. B. Bubb
Polytechnic Institute, Brooklyn, N. Y.	March 9	W. D. Ennis	J. S. Kerins	Percy Gianella
State Agri. College, Corvallis, Ore.	March 9	Thos. M. Gardner	C. L. Knopf	S. H. Graf
Purdue University, Lafayette, Ind.	March 9	L. V. Ludy	H. A. Houston	J. M. Barr
University of Kansas, Lawrence, Kan.	March 9	P. F. Walker	C. E. Johnson	C. A. Swiggett
New York Univ., New York	November 9	C. E. Houghton	Harry Anderson	Andrew Hamilton
Univ. of Illinois, Urbana, Ill.	November 9	W. F. M. Goss	B. L. Keown	C. S. Huntington
Penna. State College, State College, Pa.	November 9	J. P. Jackson	G. B. Wharen	G. W. Jacobs
Columbia University, New York.	November 9	Chas. E. Lucke	F. R. Davis	H. B. Jenkins
Mass. Inst. of Tech., Boston, Mass.	November 9	Gaetano Lanza	Morrill Mackenzie	Foster Russell
Univ. of Cincinnati, Cincinnati, O.	November 9	J. T. Faig	H. B. Cook	C. J. Malone
Univ. of Wisconsin, Madison, Wis.	November 9	C. C. Thomas	John S. Langwill	Karl L. Kraatz
Univ. of Missouri, Columbia, Mo.	December 7	H. Wade Hibbard	R. V. Aycock	Osmer Edgar
Univ. of Nebraska, Lincoln 'Neb.	December 7	C. R. Richards	W. J. Wohlenberg	W. H. Burleigh
	1910			
Univ. of Maine, Orono, Me.	February 8	Arthur C. Jewett	H. N. Danforth	A. H. Blaisdell
Univ. of Arkansas, Fayetteville, Ark.	April 12	B. N. Wilson	C. B. Boles	W. Q. Williams

ADVERTISING SUPPLEMENT

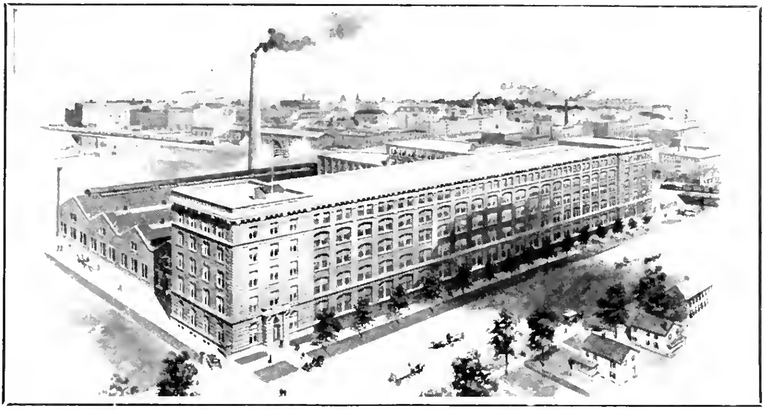
SECTION 1

Machine Shop Equipment

THE WARNER & SWASEY COMPANY

CLEVELAND, OHIO, U. S. A.

BRANCH OFFICES: NEW YORK DETROIT CHICAGO



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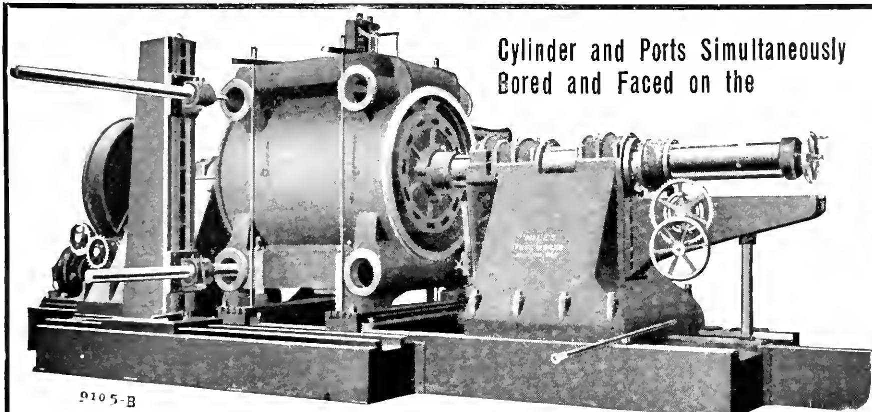
See also advertisement page 8—Hollow Hexagon Turret Lathes and Turret Screw Machines



Niles Corliss Cylinder Boring Machine

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Shop Management

Papers read before

The American Society of Mechanical Engineers from 1890 to 1908

The Society has a limited number of copies of papers on Shop Management which have been presented before it. Orders will be filled until the supply is exhausted.

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23—928	Bonus System of Rewarding Labor, H. L. Gantt.....	.20
8—239	Capital's Need for High-Priced Labor, W. E. Partridge	.20
24—998	Drawing Office Equipment, John McGeorge	.20
5—143	Drawing Office System, H. R. Towne..............	.10
24—965	Gift Proposition for Paying Workmen, F. Richards..	.20
24-1002	Graphical Daily Balance in Manufacture, H. L. Gantt.	.20
25-1012	Is Anything the Matter with Piece Work? F. Richards	.20
24-1001	Machine Shop Problem, C. Day.................	.20
18—711	Method of Determining Selling Price, H. M. Lane..	.20
18—739	Method of Shop Accounting, H. M. Lane..........	.10
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16—647	Piece Rate System, F. W. Taylor.................	.30
12—449	Premium Plan of Paying for Labor, F. A. Halsey..	.20
8—256	Problem in Profit Sharing, Wm. Kent..............	.30
25-1040	Rational Basis for Wages, H. Emerson............	10
24-1003	Shop Management, F. W. Taylor...............	.90
7—209	Shop Order System of Accounts, H. Metcalfe.......	.40
9—287	Short Way to Keep Time and Cost, H. L. Binsse...	.10
25-1010	Slide Rules for the Machine Shop, C. G. Barth......	.20
27-1115	History of a System of Shop Management, J. M. Dodge	.10
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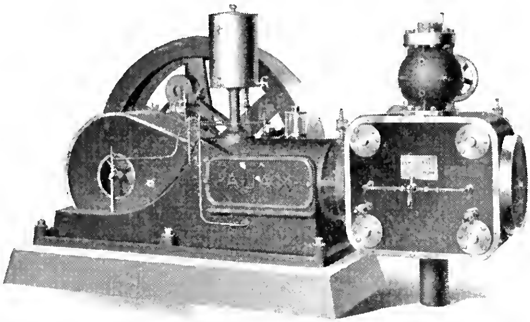
ADVERTISING SUPPLEMENT

SECTION 2

Power Plant Equipment



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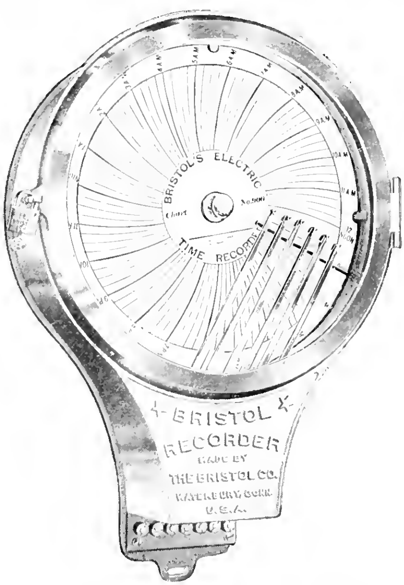

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illustrated herewith adapted for recording, occurrence and duration of a great variety of mechanical operations.

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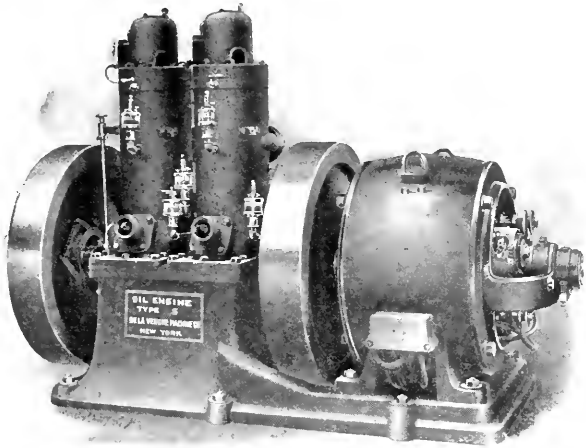
No Electrical Ignition
No Carbureter



10 Kilowatt Generator Set

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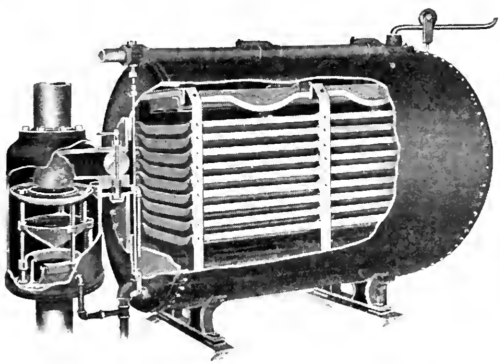

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ADVERTISING SUPPLEMENT

SECTION 3

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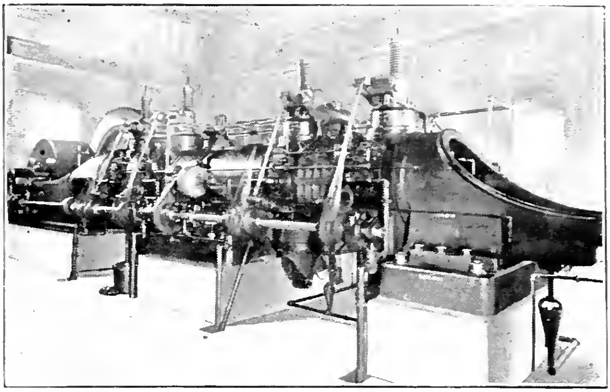

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Steam Turbines, Steam Engines, Gas Engines, Gas Producers, Condensers and Mechanical Stokers

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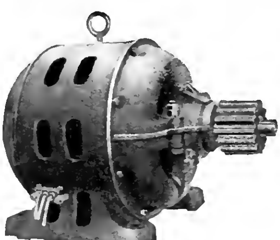
Westinghouse

Type "MS" Squirrel Cage A. C. Mill Motors



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Squirrel cage induction motors designed especially for operating conditions found in steel mills, cement mills, etc.

They are intended to operate continuously with almost no attention under the unusually trying conditions found in the class of industries mentioned.

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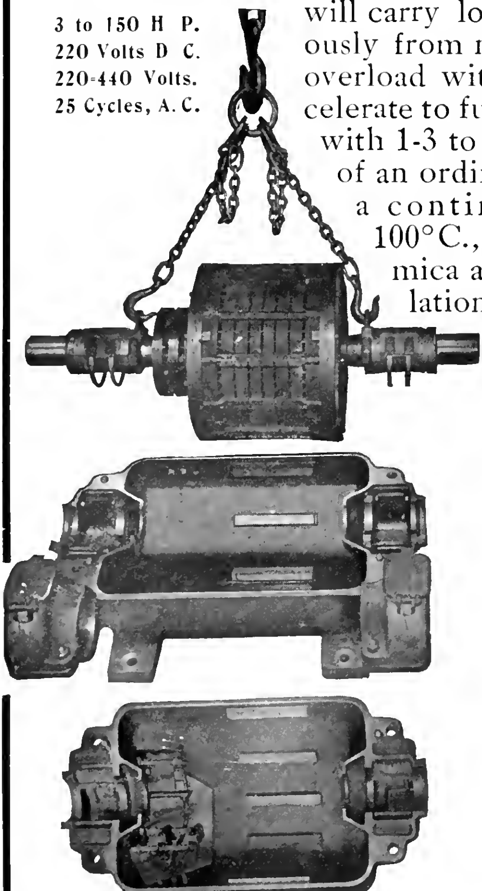
3 to 150 H P.
220 Volts D C.
220-440 Volts.
25 Cycles, A. C.



will carry loads varying instantaneously from no load to 100 per cent overload without injury. Will accelerate to full speed in a given time with 1-3 to 1-4 the required power of an ordinary motor. Will stand a continuous temperature of 100° C., owing to the fire-proof-mica and woven asbestos insulation. Will operate in dusty atmospheres, as they are totally enclosed.

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SECTION 4

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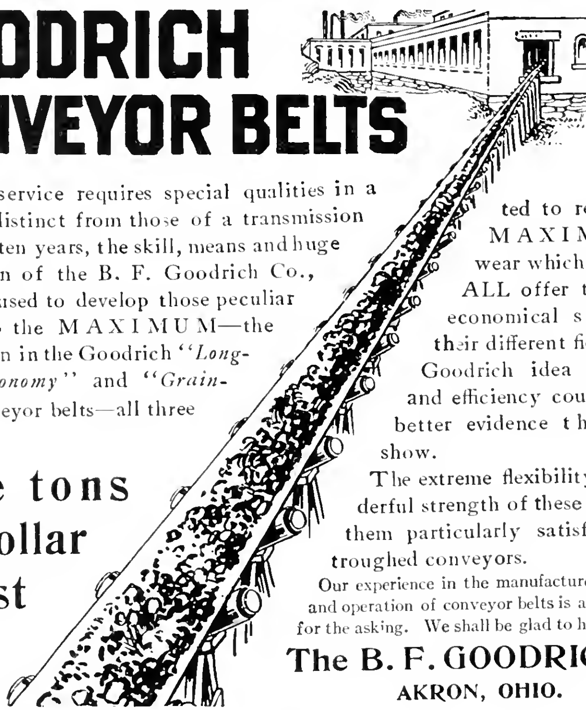
GOODRICH CONVEYOR BELTS



Conveyor service requires special qualities in a belt quite distinct from those of a transmission belt. For ten years, the skill, means and huge organization of the B. F. Goodrich Co., have been used to develop those peculiar qualities to the MAXIMUM—the result is seen in the Goodrich "*Long-life*" "*Economy*" and "*Grain-belt*" conveyor belts—all three will handle

more tons per dollar of cost

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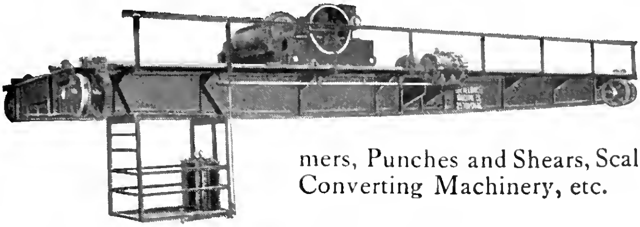

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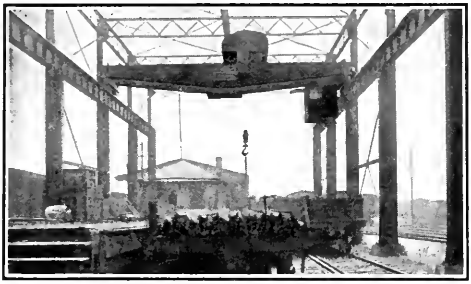

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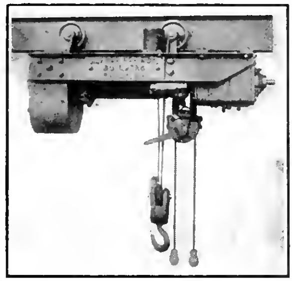

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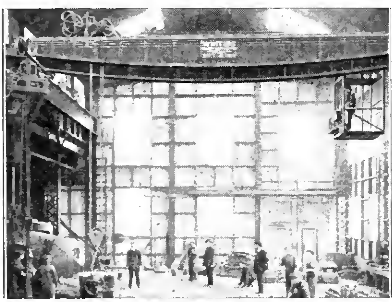

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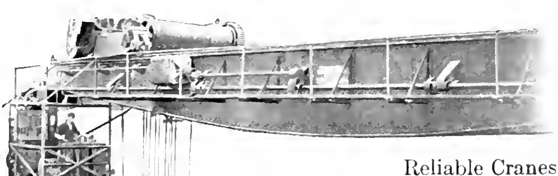

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ADVERTISING SUPPLEMENT

SECTION 5

Engineering Miscellany

ADVERTISING SUPPLEMENT

SECTION 6

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ALPHABETICAL LIST OF ADVERTISERS

INDEX TO THE JOURNAL

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

January-June, 1910

If it is desired to remove the index for the purpose of binding with The Journal for January to June, raise the staples upright, when the section will slip off easily. Then flatten the staples again.

INDEX TO JOURNAL, JANUARY-JUNE, 1910

Note: Items appearing in The Journal as Society Affairs, have the month and page number given. Where the list of discussors of a paper is given, the list appears under the straight title of the paper. Papers published in The Journal for 1909, discussion of which was published in 1910 are indicated by the month followed by "1909." All papers, reports, etc., of the Gas Power Section appear under the heading Gas Power Section. All items concerning colleges and not referring to Student Branches are indexed under Colleges. Items regarding Student Branches are so indexed. Miscellaneous items are indexed under Miscellaneous.

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THE

JOURNAL

THE AMERICAN SOCIETY
OF MECHANICAL ENGINEERS

CONTAINING
THE PROCEEDINGS

AUGUST 1910

ANNUAL MEETING, NEW YORK, DECEMBER 6–9, 1910

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ONTENTS

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The professional papers contained in The Journal are published prior to the meetings at which they are to be presented, in order to afford members an opportunity to prepare any discussion which they may wish to present.

THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 32 AUGUST 1910 NUMBER 8

MEETING IN ENGLAND

The completed program of the Joint Meeting of The American Society of Mechanical Engineers with the Institution of Mechanical Engineers, now in progress in England, is as follows:

Monday, July 25

11.15 a.m. Members of the American Society and their ladies depart from Liverpool (Lime Street Station) by special train for Birmingham. Luncheon on the train.

1.15 p.m. Arrive Birmingham (New Street Station).

3.00-6.00 p.m. The Secretaries' Office will be open at the Birmingham and Midland Institute, Paradise Street, Birmingham, for the registration of addresses, issue of badges and tickets, etc.

Tuesday, July 26

9.00 a.m. The Right Hon. The Lord Mayor of Birmingham, Alderman W. H. Bowater, *Chairman*, Nevill Chamberlain, Esq., *Chairman of the Executive Committee*, and the members of the Birmingham Reception Committee, will welcome the President, John A. F. Aspinwall, Esq., the Council and the Members of the Institution, and the President, George Westinghouse, Esq., the Council, the Officers and the Members of the American Society, in the Lecture Hall of the Birmingham and Midland Institute. Reading and Discussion of Papers.

Presiding Officer, Am.Soc.M.E., W. F. Goss.

1.00 p. m. Luncheon in the Town Hall, by kind permission of the Right Hon. the Lord Mayor (ladies invited).

ALTERNATIVE EXCURSIONS

2.20 p.m. Visit to the Pump and Power Co.'s Testing Station at the Works of the South Staffordshire Mond Gas (Power Heating) Co. Ordinary trains to and from Dudley Port. Tea, by kind invitation of the Pump and Power Co.

Or,

2.00 p.m. Visit to the works of the Austin Motor Co., Northfield, by motor cars kindly provided by the company. Tea, by kind invitation of the Austin Motor Co,

Or,

2.30 p.m. Visit to the works of the Metropolitan Amalgamated Railway Carriage and Wagon Co., by special tramcars. Tea, by kind invitation of the company.

Or,

2.30 p.m. Visit to the Frankley Filter Beds of the Birmingham Corporation Water Works, by special motor omnibuses. (Ladies invited.) Tea.

Or,

2.10 p.m. Excursion to Stratford-on-Avon. (Ladies invited.) Special train to Stratford-on Avon. Visit places of interest. Tea. Special train to Birmingham, arriving 6.45 p.m.

Or,

1.30 p.m. Excursion to Worcester. (Ladies invited.) Special train to Worcester. Luncheon on the train. Visit the Cathedral, the Worcester Royal Porcelain Works, and the "Commandery." Special train to Birmingham arriving about 6.50 p.m. Tea on the train.

Or,

2.00 p.m. Excursion to Stoneleigh Park and Kenilworth by special motor omnibuses. (Ladies invited.) Visit Stoneleigh Abbey, by kind invitation of the Right Hon. Lord Leigh, Visit Guy's Cliff. Tea. Return to Birmingham.

9-11 p.m. Garden Fête in the Botanical Gardens, Edgbaston, by kind invitation of the Birmingham Reception Committee.

Wednesday, July 27

9.00 a.m. Secretaries' Office open,

10.00 a.m. Reading and Discussion of Papers. Presiding Officer, Am.Soc. M.E., E. D. Meier.

1.00 p.m. Luncheon in the Town Hall by kind permission of the Right Hon. The Lord Mayor. (Ladies invited.)

ALTERNATIVE VISITS

2.00 p.m. To the New Buildings of the University of Birmingham, opened in July 1909, by His late Majesty, King Edward VII. (Ladies invited. Special motor omnibuses to and from the University. Tea, by kind invitation of the Council of the University.

Or,

2.30 p.m. To Messrs. Mitchells and Butlers' Brewery, by special motor omnibuses. Tea by kind invitation of Messrs. Mitchells and Butlers.

9–11 p.m. Reception in the Council House by kind invitation of the Right. Hon. The Lord Mayor of Birmingham, Alderman W. H. Bowater and The Lord Mayoress.

Thursday, July 28

ALTERNATIVE EXCURSIONS

9.25 a.m. Coventry and Rugby. Special train to Coventry. Visit either the Daimler Works or Messrs. Alfred Herbert. Luncheon by kind invitation of either the Daimler Motor Co. or Messrs. Alfred Herbert. Special train to Rugby. Visit either Messrs. Willans and Robinson, or the British Thomson-Houston Co. Special train to London, arriving 6.35 p.m. Tea on the train.

Or,

9.35 a.m. Lichfield. (Ladies invited), Special train to Hammerwich. Drive to the South Staffordshire Waterworks Co.'s Pipe Hill Pumping Station. Visit the Pumping Station. Drive to Lichfield. Visit Lichfield Cathedral. Luncheon. Visit Dr. Johnson's birthplace and other places of interest in Lichfield. Special train to London. arriving 6.55 p.m. Tea on the train.

Or,

9.00 a.m. Kenilworth, Warwick and Stratford-on-Avon, by special motor omnibuses. (Ladies invited.) Visit Kenilworth Castle. Visit Guy's Cliff. Visit Warwick Castle, by kind invitation of the Right Hon. The Earl of Warwick. Luncheon. Visit places of interest in Stratford-on-Avon. Special train to London, arriving 7.37 p.m. Tea on train.

Or,

9.00 a.m. Stratford-on-Avon, Warwick and Kenilworth, by special motor omnibuses. (Ladies invited.) Visit places of interest in Stratford-on-Avon. Luncheon. Visit Warwick Castle, by kind invitation of Right Hon. The Earl of Warwick. Visit Kenilworth Castle. Special train to London, arriving 7.37 p.m. Tea on the train.

9. p.m. Conversazione in the Institution House, Storey's Gate, St. James's Park, London, by invitation of the President and Council of the Institution.

Friday, July 29

9.30 a.m. Secretary's Office open at the Institution, Storey's Gate, St. James's Park, London.

10.00 a.m. Reading and Discussion of Papers in the Lecture Theatre of the Institution of Civil Engineers, by kind permission of their Council, Presiding Officer, Am.Soc.M.E., Chas. Whiting Baker.

3.00–5.30 p.m. Garden Parties and Visits. Cards of invitation may be obtained at the Secretaries' Office in Birmingham and in London.

7.30 p.m, Institution Dinner in the Connaught Rooms, Freemason's Hall, Great Queens S'reet, W. C. (Evening Dress.) (Ladies invited.) Reception at 7.00 p.m. Address by Prof. F. R. Hutton, Hon. Secy.

Saturday, July 30

ALTERNATIVE EXCURSIONS

10.00 a.m. Windsor and Marlow. (Ladies invited.) Special train to Windsor. Luncheon in the Guildhall, Windsor. Special steam launches to Marlow. Tea. Special train to London, arriving 7.40 p.m.

9.45 a.m. Marlow and Windsor. (Ladies invited.) Special train to Marlow. Special steam launches to Windsor. Luncheon on the launches. Tea in the Guildhall, Windsor. Special train to London, arriving 7.20 p.m.

The guests at these excursions will be invited to attend the Japan-British Exhibition and the Garden Club during the evening.

6.30 p.m. The Council, Past-Presidents of the Society and their ladies will be entertained at dinner on Saturday evening by Sir William H. White, K.C.B., Past-President of the Institution and Honorary Member of the Society, and Lady White.

Sunday, July 30

Special services in Westminster Abbey, where seats will be reserved for the membership. Inspection of Sir Benjamin Baker Memorial window.

The following papers have been assigned to the several meetings:

Birmingham, Tuesday, July 26, and Wednesday, July 27

English Running-Shed Practice; by Mr. Cecil W. Paget, Member, of Derby.

Round-House Practice, or the Handling of Locomotives at Terminals to secure continuous Operation; by Mr. Frank Henry Clark, Member, *Am.Soc.M.E.*, of Chicago

Handling of Locomotives at Terminals; by Mr. Frederic N. Whyte, Vice-President, *Am.Soc.M.E.*, of New York.

Handling Locomotives; by Mr. Henry H. Vaughan, Member *I.Mech.E.* and *Am.Soc.M.E.*, of Montreal.

American Locomotive Terminals; by Mr. William Forsyth, Member, *Am.Soc.M.E.*, of Chicago.

High-Speed Tools, and Machines to fit them; by Mr. H. I. Brackenbury, Member, of Newcastle-upon-Tyne.

Tooth Gearing; by Mr. J. D. Steven, Associate Member, of Birmingham.

Interchangeable Involute Gearing; by WILFRED LEWIS, Member, *Am.Soc.M.E.;* Discussion by C. R. GABRIEL, Member, *Am.Soc.M.E.*

Topical Discussion on High-Speed Tools, by Members of the *Am.Soc.M.E.*

London, Friday, July 29

Electrification of Suburban Railways; by Mr. F. W. CARTER, of Rugby.

Cost of Electrically-Propelled Suburban Trains; by Mr. H. M. HOBART, of London.

Economics of Railway Electrification; by Mr. WILLIAM B. POTTER, Member, *Am.Soc.M.E.*, of Schenectady, N. Y.

Electrification of Trunk Lines; by Mr. L. R. POMEROY, Member, *Am.Soc.M.E.*, of New York.

Electrification of Railways; by Mr. GEORGE WESTINGHOUSE, President, *Am.Soc.M.E.*, of Pittsburg, Pa.

The official party, comprising 160 members and guests of The American Society of Mechanical Engineers, sailed for Liverpool, Saturday, July 16, at 2 p.m., aboard the S. S. Celtic, White Star line. The Committee on Arrangements, Ambrose Swasey, *Chairman*, Charles Whiting Baker, *Vice-Chairman*, George W. Brill, W. F. M. Goss, John R. Freeman, and, ex-officio, George Westinghouse, President, F. R. Hutton, Honorary Secretary, William H. Wiley, Treasurer, and Calvin W. Rice, Secretary, and the sub-committee on Entertainment, Geo. M. Brill, *Chairman*, H. G. Reist, John W. Upp, George A. Orrok, Mrs. F. R. Hutton, Mrs. Geo. M. Brill, and Mrs. Jesse M. Smith, arranged for a most interesting program on board ship, which follows:

Sunday Religious Services

Monday Evening Reception by the officers and Past-Presidents of the Society

Tuesday Evening Illustrated Address. "What are the Astronomers Doing?" Worcester R. Warner, Past-President

Wednesday Evening Musicale

Thursday Evening Illustrated Address. "Construction of the Panama Canal," John R. Freeman, Past-President

Friday Evening Dancing

Saturday Evening Conversazione. Collection for Seamen's Benefit Fund. Awarding of Prizes

Sunday Religious Services

Bridge, deck games, etc., were arranged for several afternoons, and inspection trips were made daily under the direction of the officers of the ship. A dainty booklet, entitled Our Ocean Trip, containing the program, committees, etc., with blank pages for notes and autographs was furnished to each of the party, and served as a useful souvenir. The members presented to Captain A. E. Hambleton of the Celtic a beautifully wrought silver cabinet, and to the Chief Engineer, Mr. C. C. Lapsley, a reading lamp with Tiffany favrile glass shade, both suitably engraved.

The comfort of the party was further provided for by the sub-committees on Transportation, Charles Whiting Baker, Calvin W. Rice; on Publishing and Printing, F. H. Hutton, F. R. Low; on Finance, Wm. H. Wiley; and on Acquaintanceship, Dr. W. F. M. Goss. This last committee met on board ship on Saturday evening and arranged for the introduction of the members of the party to one another.

It is a matter of much regret that President Westinghouse was at the last moment prevented from attending the meetings, which in his absence will be presided over by W. F. M. Goss and Charles Whiting Baker, Vice-Presidents.

A running account of the meeting will be prepared by Calvin W. Rice, Secretary of the Society, for publication in the fall.

The party on the Celtic is to be joined in England by other members and guests now in Europe or going by other routes, and the total number cannot be announced until the final registration at the meetings in England. Following is a list of those sailing on the Celtic:

Adams, Miss, New York, with Hon. and Mrs. Wm. H. Wiley
Aldrich, John G., Providence, R. I.
Alford, L. P. New York
Alford, Mrs., New York
Armstrong, Miss, Elizabeth N. J., with Mr. and Mrs. S. L. Moore
Baldwin, Abram T., Detroit, Mich.
Barnes, Howel H., Jr., New York
Bevin, Sydney, Walden, New York
Bevin, Mrs., Walden, New York
Brill, Geo. M., Chicago, Ill.
Brill, Mrs., Chicago, Ill.
Brill, Elliot M., Chicago, Ill.
Brill, G. Meredith, Chicago, Ill.
Brooks, J. Ansel, Providence, R. I.
Bump, Burton N., Syracuse, N. Y.
Bump, Mrs., Syracuse, N. Y.
Burlingame, L. D., Providence, R. I.
Burlingame, Mrs., Providence, R. I.
Burlingame, Miss, Providence, R. I.
Bursley, Jos. A., Ann Arbor, Mich.
Bursley, Mrs., Ann Arbor, Mich.
Calder, John, Ilion, N. Y.
Calder, Mrs., Ilion, N. Y.
Camp, Geo. E., Utica, N. Y.
Clarke, C. W. E., New York
Cobleigh, H. R., New York
Coffin, Mrs., Charles H., New York with Mr. and Mrs. Jesse M. Smith
Colwell, Augustus W., Columbus, O.
Corbett, Charles H., Brooklyn, N. Y.
Corbett, Mrs., Brooklyn, N. Y.
Dart, Wm. C., Providence, R. I.

Davis, Chas. Ethan, Muncie, Ind.
Davis, Mrs., Muncie, Ind.
Dean, F. W., Boston, Mass.
Dodge, James M., Past-Pres., Philadelphia, Pa.
Dodge, Mrs., Philadelphia, Pa.
Dodge, Miss, Philadelphia, Pa.
Dodge, Karl, Philadelphia, Pa.
Durfee, Walter C., Jamaica Plain, Mass.
Durfee, Miss, Jamaica Plain, Mass.
Foster, Miss, New York, with Mr. and Mrs. Augustus Smith
Freeman, John R., Past-Pres., Providence, R. I.
Freeman, Mrs., Providence, R. I.
Galloupe, Francis E., Boston, Mass.
Galloupe, Chauncy Adams, Boston, Mass.
Gantt, H. L., Manager, New York
Gantt, Mrs., New York
Gleason, Wm., Rochester, N. Y.
Goss, W. F. M., Vice-Pres., Urbana, Ill.
Goss, Mrs., Urbana, Ill.
Goss, Miss, Urbana, Ill.
Greene, Arthur M., Jr., Troy, N. Y.
Greene, Mrs., Troy, N. Y.
Hallenbeck, Geo. E., Toledo, Ohio
Hamilton, Chester B., Jr., Toronto, Can.
Hartness, James, Manager, Springfield, Vt.
Hartness, Mrs., Springfield, Vt.
Hartness, Miss, Springfield, Vt.
Hartness, Miss Helen E., Springfield, Vt.
Higgins, C. P., Roselle, N. J.
Higgins, Mrs. Roselle, N. J.
Hillyer, Geo., Jr., Atlanta, Ga.
Honsberg, August A., Cleveland, Ohio
Hutton, F. R., Past-Pres., Hon. Secy., New York
Hutton, Mrs., New York
Johnson, A. L., Muncie, Ind.
Johnson, Mrs., Muncie, Ind.
Keep, W. J., Detroit, Mich.
Keep, Mrs., Detroit, Mich.
Keep, Miss, Detroit, Mich.
Klepinger, J. H., Great Falls, Mont.
Klepingei, Mrs., Great Falls, Mont.
Klock, Frank B., Syracuse, N. Y.
Latham, H. M. Worcester, Mass.
Leland, Henry M., Detroit, Mich.
Leland, Mrs., Detroit, Mich.
Lewis, Wilfred, Philadelphia, Pa.
Lodge, William, Cincinnati, Ohio
Lodge, Mrs., Cincinnati, Ohio.
Low, F. R., New York
Low, Mis., New York
McCreery, J. H., New York
Main, Charles T., Boston, Mass.
Main, Mrs., Boston, Mass.
Main, Miss, Boston, Mass.
Main, Theodore, Boston, Mass.
Marburg, L. C., New York
Miller, Spencer, New York
Miller, Spencer, Jr., New York
Moore, S. L., Elizabeth, N. J.
Moore, Mrs., Elizabeth, N. J.
Morrin, Thos., San Francisco, Cal.
Morrin, Mrs., San Francisco, Cal.
Nelson, James W., New York
O'Neil, J. G., Chicago, Ill.
O'Neil, Mrs., Chicago, Ill.
Orrok, Geo. A., New York
Parson, Charles H., New York
Parson, Mrs., New York
Phalen, Miss, niece of Wm. Gleason, Rochester, N. Y.
Platt, John, New York
Plunkett, Charles T., Adams, Mass.
Plunkett, Chas. T., Jr., Adams, Mass,
Reed, E. Howard, Worcester, Mass.
Reed, Mrs., Worcester, Mass.
Reid, Joseph, Oil City, Pa.
Rice, Calvin W., Secretary, New York
Richmond, Knight C., Providence, R. I.
Roe, J. W., New Haven, Conn.
Sague, J. E., Albany, N. Y.
Sague, Mrs., Albany, N. Y.
Sague, Miss, Albany, N. Y.
Sanford, Geo. R., Syracuse, N. Y.
Smith, A. Parker, New York
Smith, Mrs., New York
Smith, Augustus, New York
Smith, Mrs., New York
Smith, Jesse M., Past-Pres., New York
Smith, Mrs., New York
Smith, Oberlin, Past Pres., Bridgeton, N. J.
Smith, Mrs., Bridgeton, N. J.
Stillman, F. H., New York
Stillman, Mrs., New York
Struckmann, H., St. Louis, Mo.
Struckmann, Mrs., St. Louis, Mo.
Such, Miss, New York, with Mr. and Mrs. Augustus Smith
Swasey, Ambrose, Past-Pres., Cleveland, Ohio
Swasey, Mrs., Cleveland, Ohio
Thompson, B. L., Syracuse, N. Y.
Thurston, Edw. D., Jr., New York
Thurston, Mrs., New York
Turner, Charles P., New York
Upp, John W., Schenectady, . Y.
Upp, Mrs., Schenectady, N. Y.
Upp, John W., Jr., Schenectady, N. Y.
Waldo, Leonard, New York
Warner, Worcester R., Past-Pres., Cleveland, Ohio

Warner, Mrs., Cleveland, Ohio
Watson, William, Boston, Mass.
Wells, F. O., Greenfield, Mass.
Wells, Mrs., Greenfield, Mass.
Wells, Miss, Greenfield, Mass.
Wheeler, Seth, Albany, N. Y.
Wheeler, Mrs., Albany, N. Y.
Wiley, Wm. H., Treasurer, New York
Wiley, Mrs., New York
York, L. D., Porthsmouth, Ohio
York, Robert, Memphis, Tenn.

NECROLOGY

MARK BARY

Mark Bary, Associate Member of the Society, who died December 27, 1909, was born at Detroit, Mich., on June 27, 1873.

Immediately after his graduation from the University of Michigan in the class of 1897, Mr. Bary entered the employ of the Michigan Electric Company, as assistant, and later in the same year was engaged as instrument man with the Missouri River Company. For the next two years Mr. Bary was employed by Bryan and Humphrey as assistant in electrical and mechanical work and as superintendent in their office. In March 1900 he became engineer-in-charge of the Laclede Power Company at St. Louis, Mo., and later in the same year engineer of construction of the city lighting plant of the Imperial Electric Light Company, St. Louis. In 1901 Mr. Bary became first assistant to H. H. Humphreys, consulting engineer, his chief work being the mechanical design and superintendence of installation of electrical and mechanical power plants. From 1904 to 1907 he was engaged in consulting practice under his own name in St. Louis.

Mr. Bary was a member of the St. Louis Society of Civil Engineers and the Disraeli Society of St. Louis. He entered The American Society of Mechanical Engineers in 1903.

RALPH WALDO EMERSON

Ralph Waldo Emerson, Associate Member of the Society, was born at Orland, Me., March 18, 1872, and received his early education at the country schools and the Phillips Andover Academy. In 1890 he entered the Worcester Polytechnic Institute where he received his technical training, leaving there in 1893 before graduation, to serve an apprenticeship with Brown and Sharpe of Providence, R. I. He remained here for two years and was subsequently connected with the American Wheelock Engine Company and the Norton Emery Wheel Company. In 1898 Mr. Emerson accepted a position as draftsman with the Cereal Machine Company of Worchester, Mass.,

known later as the Shredded Wheat Company and was responsible for much of the special machinery. When the company moved to Niagara Falls, he took charge of the layout and equipment of the plant, and from draftsman rose to the position of mechanical engineer. In 1904 he became Master Mechanic of the Case Factory of the Singer Manufacturing Company, South Bend, Ind., with which company Mr. Emerson was connected until some six months ago when, as mechanical engineer and factory economist, he opened an office of his own.

In coöperation with Frank Bishop, Mem. Am.Soc.M.E., Mr. Emerson invented and patented a refrigerating machine for domestic use.

Mr. Emerson was a member of the Commercial-Athletic Club of South Bend.

THOMAS H. SAVERY

Thomas H. Savery was born in Philadelphia, Pa., on May 31, 1837, and died at his home in Wilmington, Del., April 5, 1910. He was educated at the Westown Boarding School and later at Friends' Select School, Philadelphia. When sixteen years of age he was apprenticed as a machinist to William Sellers and Company of Philadelphia, with which firm he remained for five years, becoming at the completion of his term of service general foreman of the Columbus machine shops of the Columbus, Piqua and Indianapolis Railroad, and later foreman of the Altoona shops of the Pennsylvania Railroad. In January 1864, he accepted a position as superintendent of Pusey and Jones Company of Wilmington, Del., was admitted as a partner, and was connected with the company as vice-president and then as president until his retirement in 1907 from active service. Mr. Savery was chiefly interested in the development of paper machinery and it was through his efforts and inventions that the Pusey and Jones Company became the acknowledged leaders in building paper machinery.

At the time of his death he was president of the Harpers Ferry Paper Company, the Shenandoah Pulp Company and the Harpers Ferry Electric Light and Power Company. He was also a director in numerous other companies in Wilmington, Philadelphia and other cities.

WM. P. BETTENDORF

Wm. P. Bettendorf was born in Mendota, Ill., July 1, 1857, and died at his home in Bettendorf, Iowa, on June 3, 1910.

His career as a mechanic and inventor began with the termination of his apprenticeship as machinist in the Peru Plow Company, Peru, Ill., in 1878. The following three or four years were devoted to the design and manufacture of farm implements at Moline and Canton, Ill. In 1882 he returned to Peru, accepting a position as superintendent of the Peru Plow Company and shortly afterward invented the now famous Bettendorf metal wheel, still used in fully ninety per cent of the agricultural implements made in the west. He also designed the full line of special machinery for the manufacture of steel wheels, from a wheelbarrow wheel to a grain harvester.

The Peru Plow Company being very limited in capital and manufacturing capacity, Mr. Bettendorf organized the Bettendorf Metal Wheel Company at Davenport, Iowa. With this company he severed his connections in 1891 and turned his attention to designing an all-steel running gear for farm wagons. This task, seemingly simple, but in reality of prodigious proportions, led him into hydraulics and intricate die-working before its final accomplishment. The gear was made entirely of sheet steel pressed into shape by special hydraulic presses and elaborate dies, and was the first with a tapering spindle to accomodate any size standard wood wagon wheel.

While perfecting the steel wagon gear, it occurred to Mr. Bettendorf that the ordinary truck for freight cars could be greatly simplified, the number of parts and weights reduced and the strength increased. His efforts along these lines resulted in the Bettendorf brake beam, pressed from sheet steel similar to the axles of the steel wagon gear. That which will prove an enduring monument to his memory as a car builder is the design of steel underframing for freight cars and the highly advanced methods for its manufacture.

Mr. Bettendorf became a member of the Society in 1895. He was also a member of the Western Railway Club, the New York Railway Club, the Railway Club of Pittsburg, the Eastern Railway Club, the New York Mechanical Club, the American Foundrymens Association, the Union League Club, and the Chicago Athletic Association.

CHARLES FREDERICK FOSTER

Charles Frederick Foster was born in Boston, Mass., September 28, 1852. He was educated in the public schools of Boston and the Punchard Free School of Andover, Mass., from which he was graduated in 1869. At the age of seventeen he began his engineering career as rodman, then as leveler and transitman in the office of the City

Engineer of Boston, where he remained until 1872. The next three years were spent with the Lowell and Andover Railroad and in the Water Works of Lawrence, Mass. Subsequent to this he became an assistant to Walter McConnell in general engineering in and around Boston; and from 1876 to 1880 occupied the position of mechanical engineer and superintendent of the St. Louis Cotton Factory. In 1873 he became assistant engineer of the Heine Safety Boiler Company. In 1893 Mr. Foster was identified with the World's Columbian Exposition at Chicago, and it was due to his excellent work and energy that the task of construction was completed in time and the fair opened on the date set. He was also connected with the International Exposition, Atlanta, Ga., as mechanical and electrical engineer and with the Universal Exposition at St. Louis, Mo., held in 1904, as chief operating engineer.

In 1905, he returned to Chicago and resumed his private practice, devoting his spare time to the compilation of engineering data which unfortunately his sudden death on May 8 left unfinished.

Mr. Foster was a member of the Western Society of Engineers and the Engineers Club of St. Louis. He became a member of The American Society of Mechanical Engineers in 1890.

The Western Society of Engineers records in its minutes: "Mr. Foster will be best remembered for his wonderful power of thought concentration; his indomitable energy; his deductive mind; his mastery of detail; his executive ability; his skill in handling large bodies of men and molding them into a concrete, harmonious, forceful working unit; his connection with various universal expositions; and by his intimates for his lovable character and amiable disposition."

THE MECHANICAL ENGINEER AND THE TEXTILE INDUSTRY

By H. L. Gantt, Published in The Journal for May

The following addition to his paper was given orally by Mr. Gantt in presenting it before the Society at the Spring Meeting and should therefore be considered a part of the paper.—Editor.

20 It has been stated that the colleges are turning out power plant engineers. Professor Rautenstrauch in his paper really makes a plea for the mechanical engineer to broaden his field, and it is my experience also, that the mechanical engineer in school lays a great deal of stress on the power plant engineer, often to the comparative neglect of the engineer engaged in other industrial enterprises. The field of the mechanical engineer today seems to be industrial. He is needed in all kinds of industries. Up to this time his attention has been confined largely to the power portion, and almost exclusively to the metal working portion of our industry.

21 By accident, having always been engaged in the metal working industry until a few years ago, I got into the textile industry, and am also familiar with some other industries, and I am satisfied that the field for the mechanical engineer in the non-metal working industries is as large, if not far larger than the metal working industries, since the latter have been developed to a much higher state of perfection than the former.

22 At a meeting of the National Metal Trades Association in New York at which I was present, statistics were given as to the decreasing cost of production of machines of various kinds. Those in attendance were largely engineers and manufacturers, whose business it is to manufacture cheaply, and who were interested in effecting shop economies. Shortly afterwards I read a paper in Boston before the Cotton Manufacturers' Association of New England and there I found comparatively few people who were familiar with the details of their shop. They were more skilful as merchants, for the high price of their raw materials, cotton, for instance, was such as to make the buying and selling end of their business much more important in their eyes than the actual process of manufacturing. The best talent was de-

voted to the buying and selling end and they knew but little about the details of manufacture in many cases.

23 Until the average cotton mill owner comes to the conclusion that something more is needed to make a manufacturer than a classical education, this situation will continue. The value of the mechanical engineer in this field has not yet been realized.

TEST OF A 15,000-KW. STEAM-ENGINE-TURBINE UNIT

By H. G. Stott and R. J. S. Pigott[1], New York, Published in The Journal for March 1910

ABSTRACT OF PAPER

This paper relates to the installation of low-pressure turbines at the 59th Street station of the Interborough Rapid Transit Company, New Yoık, originally equipped with engines of the Manhattan type, which are double engines having a 42-in. horizontal high-pressure cylinder and an 86-in. vertical low-pressure cylinder with a 5000-kw. generator. The generator is capable of carrying a load of 8000 kw. continuously, but the best economy is obtained at about 5000 kw. In considering the means for increasing the power of the station, it was finally decided to add low-pressure turbines to operate on exhaust steam from the engines.Three turbines have been installed of the vertical, 3-stage, impulse type, having six fixed nozzles and six which can be operated by hand, so as to control the back pressure on the engine over the division of load between engine and turbine. The tuıbines drive generators of the 3-phase induction type of 7500-kw. normal capacity. By the addition of the turbine the engine can be ıun to the full capacity of its generator, to which is added the current from the turbo-generator, making a total output of 15,000 kw. The net results obtained by the installation, as indicated by the tests reported in the paper are summarized as follows:

a An increase of 100 per cent in maximum capacity of plant.

b An increase of 146 per cent in economic capacity of plant.

c A saving of approximately 85 per cent of the condensed steam for retuın to the boilers.

d An average improvement in economy of 13 per cent over the best high-pressure turbine results.

e An average improvement in economy of 25 per cent (between the limits of 7,000 kw. and 15,000 kw.) over the results obtained by the engine units alone.

f An average thermal for the unit efficiency between the limits of 6500 kw. and 15,500 kw. of 20.6 per cent.

ADDITION TO PAPER

The following addition to the paper was given orally by Mr. Pigott in presenting it before the Society at its meeting in New York in March, and should therefore be considered a part of the paper.—Editor.

[1] Assistant Engineer, Fifty-Ninth Street Station of the Interborough Rapid Transit Company.

25 The first point which presents itself in view of the remarkable results of these tests, is the question of accuracy of measurement. The actual unit water-rate is dependent upon three factors only: quality of steam entering the engine, kw. load, and weight of water per hour. The quality of high-pressure steam is easily and accurately determined by means of the ordinary throttling calorimeter. The load on the machines was determined by means of nine integrating meters: two meters each on turbine, engine and total load, connected by the 2-meter method; one balanced 3-phase meter each on turbine, engine, and total load. Each meter was calibrated once a week, and the error was always within one-half of 1 per cent.

26 The weight of water from the turbine hot-well was determined by a pair of 40,000-lb. standard platform scales, with a recording device in addition to the hand weighing. The load was about 25,000 lb. per scale, the limitation being the size of the tanks on the scales. These scales are graduated to 5 lb. and will balance to 2 or 3 lb., so that the error in reading is negligible. Receiver trap water and low-pressure separator water were weighed together on a pair of 2000-lb. platform scales, reading to $\frac{1}{2}$ lb. All scales were calibrated with standard 50-lb weights before testing.

27 The actual trap water weight was obtained by interposing a 1-in. Venturi meter with recording device in the line to the scales; this was also calibrated by scales and found correct to less than 1 per cent, and the low-pressure separator water obtained by difference.

28 For examination of thermodynamic conditions within the machines, the most important determination is that of quality of the low-pressure steam to the turbine, since on this depends one of the important corrections to guaranteed conditions. There were no experimental data available that we could discover, bearing on low-pressure quality determinations, so the investigation was made incidental to the tests, from which the following was established. The ordinary standard perforated pipe sampler is absolutely worthless in giving a true sample, and it is vital that the sample be abstracted from the main without changing its direction or velocity until it is safely in the sample pipe and entirely isolated from the rest of the steam. Multiple orifice nozzles are of no use, as in all cases one orifice will supply practically all the steam, leaving the others useless. After much experimenting with various styles of samples, all of which were failures, the single orifice curved tube (Fig. 34) was adopted.

29 The reason for failure of other styles is plain; if any sudden turn is made by the wet steam in entering the sample nozzle, the

entrained moisture, by reason of its immensely greater specific gravity and slight skin friction in the tenuous surrounding fluid, will continue with unchanged direction and a dry sample will enter the nozzle. In

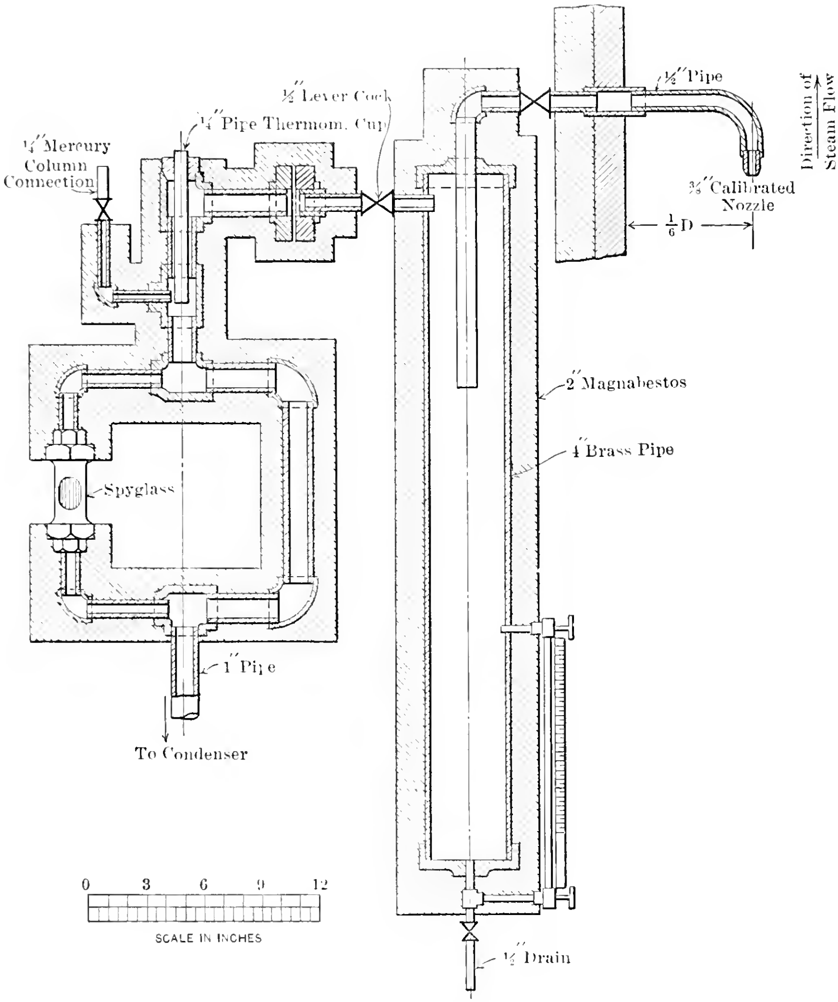

Fig. 3 Low-Pressure Separating-Throttling Calorimeter

other words, the sampler becomes a very fair separator. Again, if the velocity in the sampler is greater than that in the main, even though there be no separating action with the proper sampler, the

steam will accelerate into the nozzle, and the moisture will not, giving a dry sample; and the reverse is true if the velocity is less in the sampling nozzle than in the main. The reason this very simple action has not been noted in connection with high-pressure steam is the smaller difference in specific gravity of water and steam, the enormously greater skin friction and the small percentage and highly-divided state of the moisture present.

30 The successful types of calorimeter for very wet steam were the Thomas electric, and a combination of a separating calorimeter with a throttling calorimeter. By the use of the separating calorimeter most of the moisture was removed, and the small remainder was registered by the throttling calorimeter. At first glance it seems as if, with an initial pressure of 12 lb. to 20 lb. absolute, the throttling calorimeter has no capacity, but by putting a vacuum of 28 in. on the discharge side of the calorimeter, an available heat is obtained sufficient to evaporate 2 or 3 per cent of moisture. When the moisture became less than this, we used the throttling calorimeter direct, eliminating the separating calorimeter altogether. The separating-throttling combination was afterward tested for radiation loss and found to lose less than 0.1 per cent at proper flow. Fig. 34 shows this combination instrument. The large size is necessary on account of the very high specific volume of steam at low pressure.

31 Referring to Fig. 34, the $\frac{3}{8}$-in. brass nozzle on the sampler is arranged to point in exactly the opposite direction to the steam flow; the lip of the nozzle is filed to a knife-edge to avoid disturbing the steam current around the sampler mouth by impact and eddies against a sensibly thick lip. The diameter of the brass nozzle is carefully measured and, if necessary, reamed smooth. This form of sampler fulfills the requirements noted above; it takes out the sample without disturbing its direction, by virtue of its position and knife-edged orifice, and the velocity can be kept correct by determining the flow from the following simple formula:

$$w = \frac{Wa}{A}$$

where

w = lb. per hr. flow through calorimeter.
W = lb. per hr. flow through steam main
a = area of sampler nozzle
A = area of main.

The sampler is allowed to extend into the pipe one-sixth of the pipe diameter, which has been found to give practically true average flow.

32 The $\frac{1}{2}$-in. valve at the sampler is opened wide, and the $\frac{1}{2}$-in. lever cock between separating and throttling calorimeters is used to regulate the flow, the throttling action taking place at this point. The rest of the calorimeter is under vacuum, the discharge being connected to a small cooler to condense the steam and then to a volumetric measuring tank. The top of this tank, which is entirely closed except for the pipe connections, was connected with the turbine condenser by a $\frac{1}{4}$-in. pipe, which gave an available vacuum of over 28 in. without affecting the measuring in any way. The spy-glass is very useful in proving that the calorimeter is working properly, for when the superheat in the throttling calorimeter gets below 6 or 8 deg. it sometimes happens that some moisture goes by, in which case the spy-glass immediately shows it up, no matter how small the quantity. As the spy-glass is most conveniently made of $\frac{3}{4}$-in. gage glass, more area is required to take away the steam from the calorimeter, and this was done by adding a by-pass of 1-in. pipe around the spy-glass. This allows free flow to take place and does not affect the function of the glass.

33 The percentage of moisture taken out by the separating portion of the instrument divided by the total percentage of moisture gives the efficiency of the separating calorimeter, which turns out to be much lower than is ordinarily supposed, from 60 to 80 per cent.

34 For the rest of the measurements steam pressures throughout were taken with high-grade thermometers, graduated to 1 deg. and in many cases as low as 0.2 deg., as these are in every case preferable to gages for saturated steam. All pressures below 15 lb. gage and all vacua were measured by mercury column, in addition to temperatures.

35 Table 1, Steam to Auxiliaries, includes for tests 25, 22, 24, 21, 23 and 26, the circulating water pump steam only; test 27, circulating water pump and dry vacuum pump; test 29, circulating water pump, dry vacuum pump and boiler feed pump; test 30, boiler feed pump alone.

36 Fig. 11 and Fig. 11a show variation of points is due to errors in earlier low-pressure calorimetry, before the standard instruments were settled upon.

37 Table 12, the column of Unit Water-Rate Total Correction, is based on a standard vacuum of 28.72 in. instead of 28.5 in., as the higher figure was the average vacuum of the series of tests. Consequently the absolute amount of correction was reduced, which is of course very desirable, in view of the uncertainty of correction factors.

38 In Fig. 14 these water rates are uncorrected for moisture, etc.

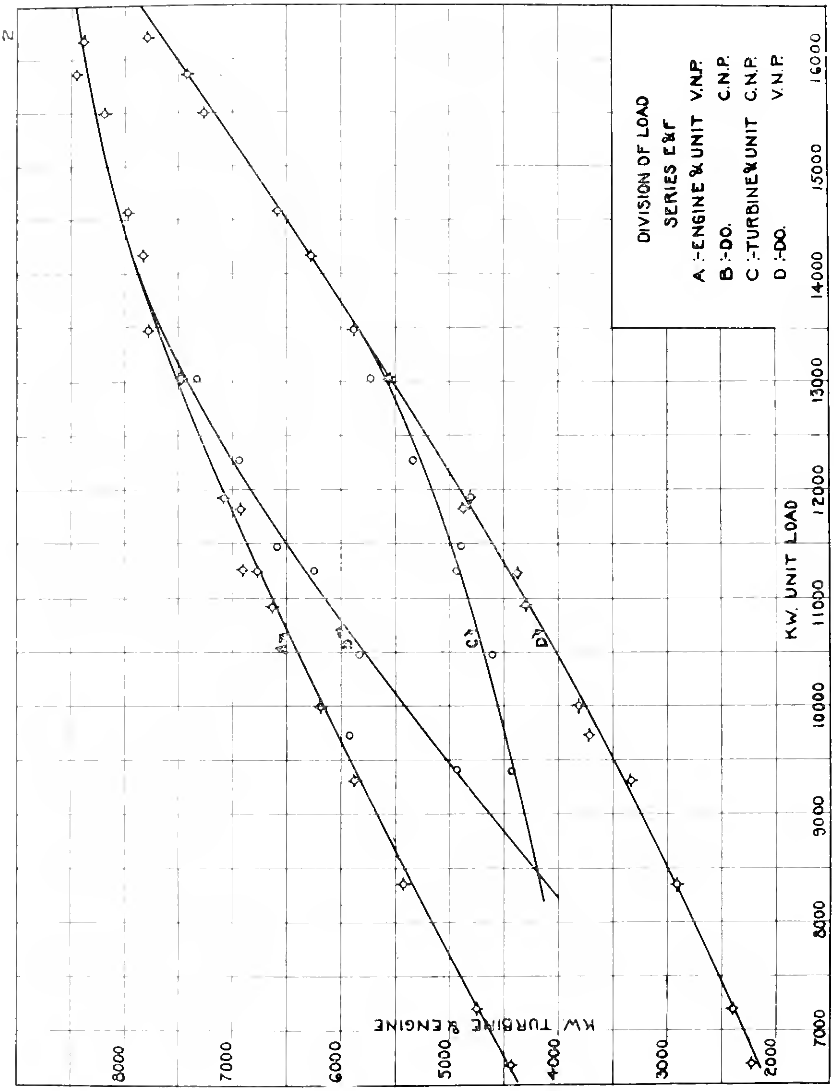

Fig. 35 Division of Load. Series E and F

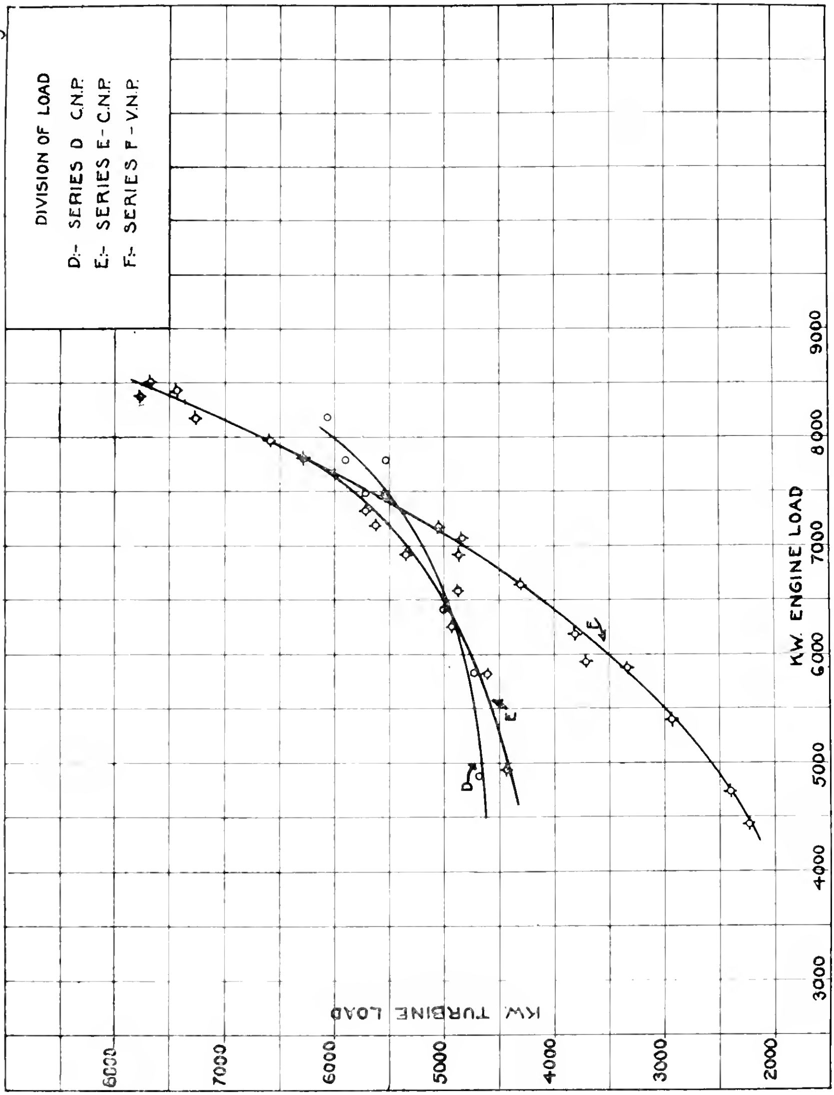

FIG. 36 DIVISION OF LOAD. SERIES D, E AND F

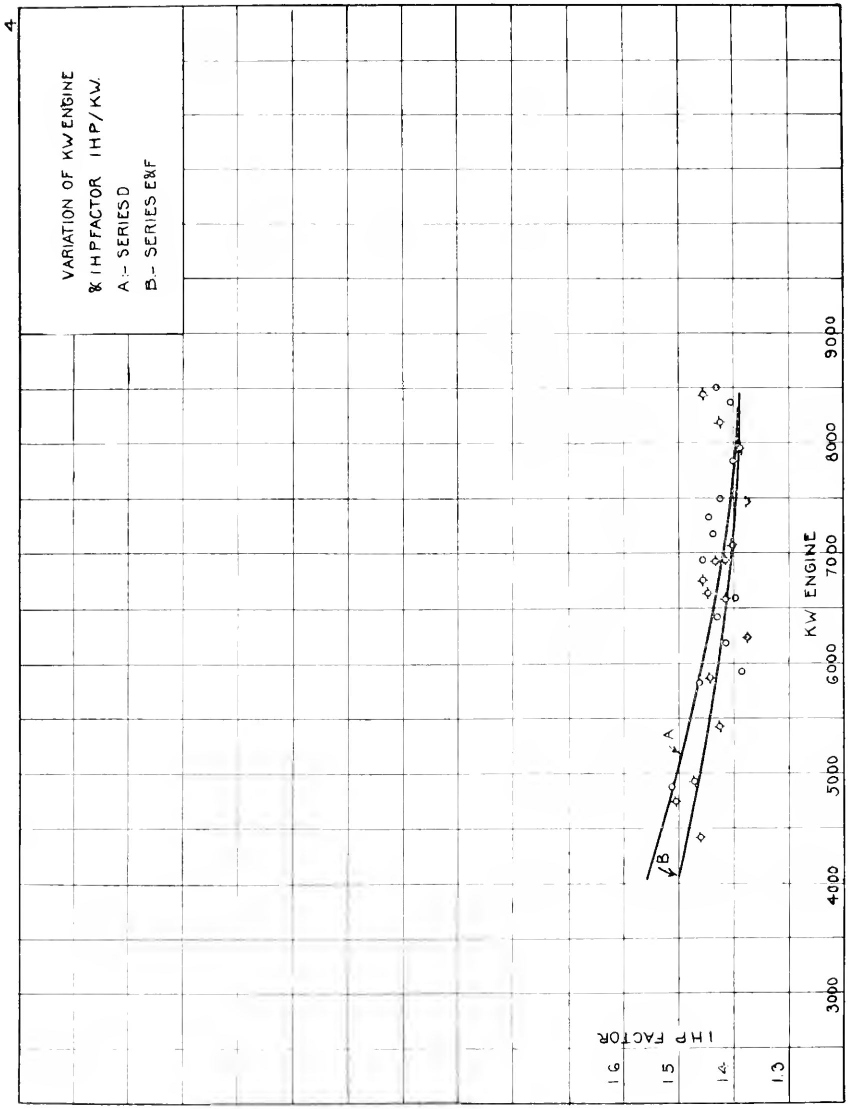

Fig. 37 Variation of Kw.-Engine and I.H.P. Factor

39 In Fig. 32 the calorimeters were drawn for the sake of clearness, as if they were situated at some distance from the sampling points; actually they were, as in Fig. 1.

40 Figs. 35, 36 and 37 serve to show the variation in load between engine and turbine, and the effect of change of efficiency of the two machines.

DISCUSSION[1]

W. L. R. Emmet. While some few applications of low-pressure turbines in connection with electric-generating engines have been put into operation before that which is described in this paper, such cases are relatively unimportant and I think that in all of them the application has been made to a station which was formerly operated non-condensing.

2 In recent years the science of steam engineering has advanced very rapidly and as the cost of fuel has increased the cost of apparatus has diminished so that we now find ourselves in a position where the question of investment is of much less relative importance than formerly, the value of the product being so very large in proportion to the cost of the apparatus required. For this reason we generally cannot afford to use any apparatus but the best, no matter how great its cost.

3. The operation of stations by turbines alone is simpler and generally more economical than that of stations which use reciprocating engines and there are many cases where it might be better to install high-pressure turbines instead of coupling low-pressure turbines with existing reciprocating engines. The results shown by Mr. Stott's paper, however, should demonstrate to many station managers that they cannot afford to run reciprocating engines alone when such an improvement can be accomplished by the addition of low-pressure

[1] During the installation and tests of the low-pressure turbines at the 59th Street station of the Interborough Rapid Transit Company, described in the above paper, a meeting of the Society was held in Boston, November 17, 1909, addressed informally by H. G. Stott on the subject of the installation. This was followed by a topical discussion on low-pressure steam turbines. On March 8, 1910, Mr. Stott and Mr. Pigott gave a complete account of the installation and tests and in what follows the discussion at both of these meetings has been combined. There has been added also an abstract of a discussion on steam turbines given at a meeting of the Society and the Engineers Club of St. Louis, in St. Louis, December 11, 1909, by G. R. Parker, Assoc.Mem.A.I.E.E.

turbines. I regret that Mr. Stott has not dwelt at more length upon the saving in investment and operation which has been effected by this installation, although his tests and explanations afford most of the data necessary for such comparisons. The increase of firing capacity due to the changes made in many of the boilers sometime ago has also contributed greatly to the remarkable improvement in this plant. Comparisons of the original conditions with the ultimate development of the present plan afford a very striking example of what can sometimes be done with an old station.

4 The results in steam consumption shown by Mr. Stott's tests are very decidedly better than the best results which have ever been accomplished with turbines alone, the advantage in water rate amounting to about 2 lb. per kw-hr. as compared with the best turbine results. When it is possible that this station will never produce power commercially more cheaply than the best modern turbine stations are now doing with equal fuel, the great value of this installation will be apparent when the enormous investment saving is considered.

5 Some of the curves given in the paper would seem to indicate that the results accomplished by the turbines were inferior to those guaranteed or expected, whereas in fact all guarantees and expectations have been rather exceeded. The reason for this apparent discrepancy is that Mr. Stott has not made allowance for the losses introduced by the presence of moisture in steam entering the turbines, whereas the guarantees on the turbines were based upon dry steam. Mr. Stott has reported the facts as they exist and as they are influenced by such methods of moisture separation as he has used. If the separation were more perfect the turbine results as shown by the curves would be much better and it is probable that with more experience, an almost complete absence of moisture in the turbine steam can be provided for. In Schenectady, where we are operating two large low-pressure turbines on exhaust steam from a reciprocating engine plant, we are running with steam which is almost completely dry. The reason for this is that the steam has to pass horizontally through a long pipe which ends in a separator and is drained before it reaches the separator. This arrangement gives the steam ample time to throw down its moisture and the last vestige of it is taken by the separator. In most applications of low-pressure turbines and engines, such an arrangement can be provided for, while in the installation referred to in this paper the delivery of steam from engine

to turbine is in a downward direction and through very short pipes in which little separation or collection of moisture into drops can occur.

MAX ROTTER. The success of an enterprise of such magnitude and novelty required, on the part of those responsible for it, a very considerable courage and confidence in engineering calculations. The test results and Mr. Stott's deductions from them will exercise no small influence on all who are interested in the production of power on a large scale.

2 One matter of practical interest is the elimination of the moisture and oil from the steam, during its passage from the engine exhaust to the turbine inlet. Tests 45 to 62 seem to show that the moisture remaining in the steam, as it entered the turbine, amounted to an average of over 4 per cent. Can it be assumed that this may be reduced to zero without re-heating or increased pressure drop? If not, then the inefficiency of the separation must be considered as one of the losses inevitable in an installation of this kind, and corrections for moisture entering the turbine should properly be omitted, as such losses would be on a par with the losses in the low-pressure stages of a high-pressure turbine, due to the water of liquefaction delivered to them from the high-pressure stages. It is not the same as a correction for moisture in the steam as originally delivered to the engine, for the engine and low-pressure turbine, with their necessary connecting elements, must be considered as a single unit and it is proper to correct only for conditions due to the imperfection of external apparatus serving the unit. For instance, while a correction for moisture in the steam would be made in testing an engine as a unital piece of apparatus, no such correction would be made in testing, as a unit, the complete plant of such engine and its boilers. The correction of 1 per cent in consumption per 1 per cent of moisture delivered to the turbine is the usual full allowance for the internal losses caused by such moisture; as obviously no deduction of the moisture itself can be made, this having been already allowed for in determining the dry steam delivered to the engine. This correction of 1 per cent is thus equivalent to the customary correction of 2 per cent in consumption per 1 per cent of moisture, as applied to a high-pressure turbine performance. The elimination of oil is probably more important as affecting the maintenance of the efficiency of the turbine and surface condenser than that of the boilers.

3 One of the most interesting features of the paper is the comparison of this engine and low-pressure turbine installation with an in-

stallation of high-pressure turbines. It is not clear whether the high-pressure turbine referred to by Mr. Stott is one of a capacity equivalent to that of the low-pressure turbine only, or to that of the combined engine and low-pressure turbine unit. The latter would certainly be proper and seems to be that considered by Mr. Stott in his statements regarding relative costs (Par. 11); but the high-pressure turbine efficiencies stated in Par. 24*d* and Fig. 19*a*, Series E and F, are apparently those of a considerably smaller machine. Nor is it quite proper to compare the efficiencies of two units on the basis of the test performance of one as against the guaranteed efficiencies of the other. A business man will not guarantee more than necessary, nor will he guarantee under any circumstances the best he can hope to do under test. Furthermore, a slight change in operating conditions might materially affect such a comparison. For instance, the majority of modern high-pressure turbine plants operate with some superheat, of which the high-pressure turbine can take greater advantage than can the engine and low-pressure turbine unit. The frequency of the turbo-alternator, in so far as it determines the speed of the turbine, will also exercise some influence upon the results. At the 59th Street station the slow speed of 750 r.p.m. is somewhat unfavorable to the turbine. A higher turbine speed would, in the case of the engine and low-pressure turbine unit, increase the efficiency of the turbine only; that is, the improvement in efficiency would apply to only about one-half of the total load of the unit; whereas, in the case of a high-pressure turbine of a capacity equivalent to that of the combined unit, the improvement in efficiency would apply to the full output of the machine. The comparative operating expenses must also be considered, and these are unquestionably lower for the high-pressure turbine than for the combined unit.

4 For the purpose of comparing the steam consumptions of the two types of apparatus, the final results given in Table 12, Series E and F, have been replotted herewith on Fig. 1 and curve A drawn through the points. This curve therefore shows the steam consumption of the combined unit, corrected to dry saturated steam at the engine throttle at 180 lb. gage, dry saturated steam at the low-pressure turbine throttle at variable pressure, and a vacuum equivalent to $28\frac{1}{2}$ in. referred to a 29.92 in. barometer. Curve B refers to a high-pressure turbine unit operating with dry saturated steam at 180 lb. gage and a vacuum of $28\frac{1}{2}$ in. referred to a 29.92 in. barometer, at a speed of 750 r.p.m., and having a capacity about equivalent to that of the combined engine-low-pressure-turbine unit. This latter curve

shows the steam consumptions it would be perfectly safe to expect from such unit under test, and it is probable that a consumption 0.3 to 0.4 of a pound lower would be attained. In making guarantees, from 1 to 1½ lb. per kw-hr. would be added. A comparison of these curves would indicate that the average difference of 8 per cent as given by Mr. Stott in Par. 14 is ample, and 13 per cent as given by him in Par. 24*d* too high.

5 To indicate the effect of a change in operating conditions, curves A and B (Fig. 2 herewith) have been plotted to show the performance of the units when operating under the conditions above mentioned, except that the steam is superheated 100 deg. fahr. It will be noted that the advantage of the combination as against the single unit is materially lowered.

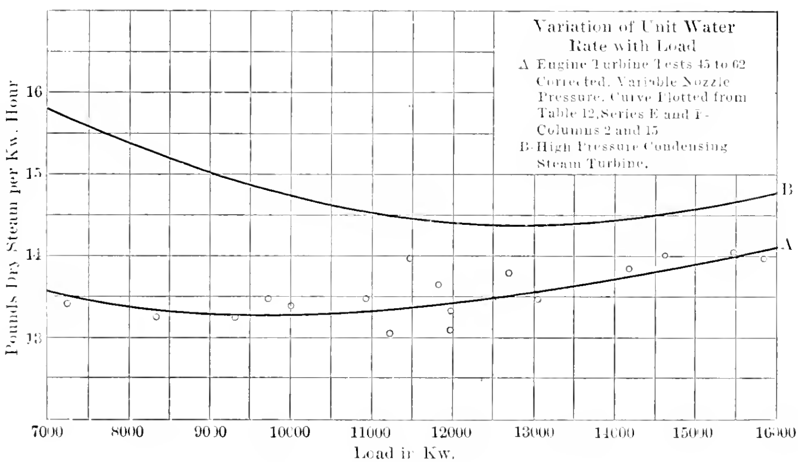

FIG. 1 RESULTS IN TABLE 12, SERIES E AND F

6 That the high-pressure turbine consumptions, as shown by the curves, are reasonable is proved by a recent unassailable test of this type of turbine, with steam at 180 lb. gage, superheated 100 deg. fahr., and a vacuum of 28¾ in. referred to a 29.92 in. barometer, which showed a consumption of 14.02 lb. per kw-hr.; the turbine having a normal capacity of only 4000 kw. at 1800 r.p.m.

7 An improvement in efficiency of 13 per cent in the 59th Street plant would almost seem to warrant a combined engine and low-pressure turbine unit as an initial installation, and it would be interesting to learn whether Mr. Stott would consider such an installation for

extensions of this plant beyond the capacity obtainable by adding low-pressure turbines to all of the existing engines.

8 The conditions for which low-pressure turbines are being considered have multiplied much faster than anticipated. For instance it has been proposed to operate a turbine by means of steam from natural geysers, which is perfectly feasible. The steam would be obtained by passing the hot water through vessels in which a pressure drop would take place and part of the water be evaporated. With such an arrangement it would be necessary to handle 30 to 50 lb. of water to obtain 1 lb. of steam at a pressure slightly below atmosphere.

9 Another use for low-pressure turbines is that of generating power from hitherto wasted industrial steam. For instance, a tur-

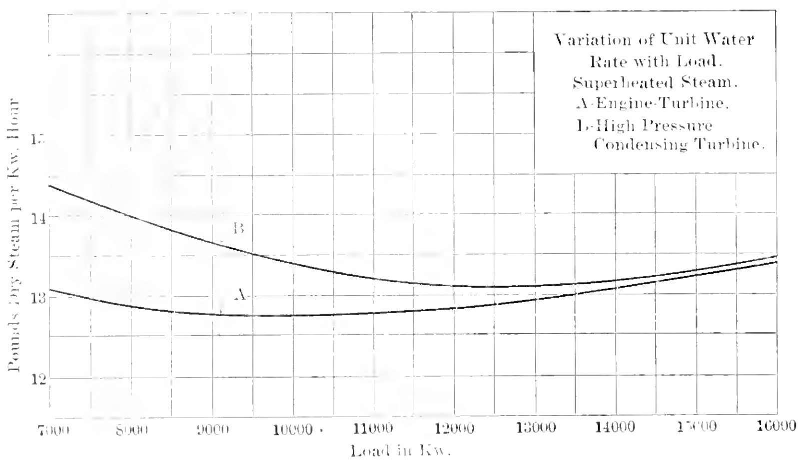

Fig. 2 Curves A and B, Showing Performance of Units when Operating under given Conditions.

bine is now being installed in an automobile tire factory where the retorts used for vulcanizing are filled with high-pressure steam for a certain period, the major portion of this steam being then blown out into the air before the retorts are opened for re-charging. This steam will henceforth be collected in a receiver, in which its pressure will drop approximately to atmospheric, and from which it will be delivered to a low-pressure turbine for use. The supply of steam is almost constant and will generate 1000 to 1200 kw., the only cost being the fixed charges, labor, and the water required for condensing.

10 Every improved method or appliance is exposed to the danger of being retarded in the progress it really merits by a few ill-advised

applications, and there are conditions under which it would be better not to advocate low-pressure turbines as additions to reciprocating engines. In almost all instances figures will show a saving of steam as achievable by such combination, but the cost of power production in a great many industrial plants is so small an item compared with the other expenses, that a reduction of even 25 per cent in fuel consumption is frequently insignificant when weighed against other considerations.

11 A low-pressure turbine should not be installed where its steam supply depends upon an old and unreliably decrepit engine. The proper thing here is an independent high-pressure condensing turbine. And as a high-pressure condensing turbine of the same capacity as the engine and low-pressure turbine combined will give so nearly the same efficiency as the combination, the boilers and the condensing apparatus will cost about the same for either installation, the fuel consumption will be about the same, and the engine can be set aside for emergency use.

12 There are numerous instances where compound engines are not overloaded but underloaded. Many of them are running non-condensing and it is a condenser and not a low-pressure turbine that is needed. The beneficial effect of adding a condenser to an underloaded compound engine is twofold: firstly, it will lower the mean effective pressure at which the engine attains its best efficiency and, therefore, if the engine is underloaded, it will bring the point of best efficiency nearer the running load; and secondly, there is the increased efficiency directly due to condensing.

13 The installation of a low-pressure turbine may also be a doubtful expedient in a plant which is being electrified and in which the engine is belted or coupled to a lineshaft so that the direct load is decreasing while the electric load is increasing. Of course a generator could be added to the engine, and a low-pressure turbine run in connection with this; but beyond the combined capacity of these it would become absolutely necessary to install a new unit. Under such circumstances the best course would be the installation of a high-pressure condensing turbine to start with.

Prof. E. F. Miller. I recently made some calculations upon the economy of the low-pressure turbine and found in figuring over some of the tests quoted an apparent efficiency of 76 to 80 per cent of that obtained from the non-conducting engine. I also worked up the efficiencies and steam consumption of the Rankine engine using

dry steam at a pressure of 15.6 lb. and exhausting at 28-in. vacuum. The same calculations were made at other pressures down to about 6 lb., as shown in Table 1. Taking the efficiency of the generator as 83 per cent and the mechanical efficiency of the engine as 90 per cent, the steam consumption per kw-hr. was obtained.

2 Assuming the ratio of efficiency of the low-pressure turbine to that of the non-conducting engine as 63, 67.5 and 72 per cent, the steam consumptions per kw-hr. were calculated. Table 1 affords a simple means by which steam consumptions may be compared.

TABLE 1 STEAM CONSUMPTIONS OF LOW-PRESSURE TURBINES AT VARYING PRESSURES

Abs. Press. at Entrance	Temp. at Entrance deg. fahr.	Abs. Press. at Exit	Temp. at Exit deg. fahr.	Quality of Steam at entrance	Quality of Steam at Exit	Thermal Eff. of Non-Cond. Eng. %
15.60	215	1.005	102	1.000	0.8785	15.93
14.13	210	1.005	102	1.000	0.8827	15.38
11.53	200	1.005	102	1.000	0.8916	14.23
9.34	190	1.005	102	1.000	0.9007	13.03
7.51	180	1.005	102	1.000	0.9125	11.75
5.99	170	1.005	102	1.000	0.9203	10.48

Abs. Press. at Entrance	Steam per h.p.-hr. of Non-Cond. Eng. per cent	Steam per kw-hr. of Non-Cond. Eng. Calling Mechanical Eff. of Eng. 90 per cent and Eff. of Generator 93 per cent	Steam Consumption per kw-hr. of Low-Press. Turbine Assuming Ratio of Act. Eff. to that of Non-Conducting Eng. as 63, 67.5 and 72 per cent		
15.60	14.72	23.55	33.6	31.4	29.4
14.13	15.23	24.36	34.8	32.5	30.4
11.53	16.50	26.40	37.7	35.2	33.0
9.34	18.09	28.94	40.1	38.6	36.2
7.51	20.13	32.20	46.0	42.9	40.3
5.99	32.66	36.26	51.8	48.3	45.3

Edward L. Clark. A number of cases have arisen where mills driven mechanically have desired to increase their power by the use of low-pressure turbines. The introduction of the low-pressure turbine in such places is accomplished in a novel and effective manner by tying the electric load and the mechanical load together by means of a synchronous motor or generator. The synchronous motor may either be belted or coupled-direct to the main lineshaft driven by the engine, and then electrically interlocked with the generator connected with the low-pressure turbine. With this method, the low-pressure

turbine requires no governor and merely delivers power in proportion to the quantity of steam exhausted by the engine.

2 It is important in the selection of a low-pressure turbine that it should be capable of utilizing the entire engine exhaust. In this arrangement, the turbine may be regarded as the low-pressure cylinder of a triple-expansion engine, and manifestly a proper ratio between the low-pressure turbine and engine cylinders should be chosen. If this feature is not observed, the expansion of the steam will not be efficiently carried out or there will be free escape of a part of the steam through the relief valve between the engine and turbine. However, a properly selected turbine will pick up the electrical load and the surplus power that it is delivering will go through the synchronous motor, thereby lightening the load of the engine. When the engine is thus relieved of a portion of its load, it naturally gives less steam to the turbine until the whole system automatically balances between the mechanical load and the electric load.

3 An important feature of operating the low-pressure turbine without a governor is that vacuum comes back on the engine at all loads, the amount of this vacuum being proportional to the amount of load carried by the turbine. By thus varying the inlet pressures on the turbine and maintaining them below atmospheric pressure, looping of the low-pressure card on the engine at light loads is avoided and the low-pressure valves operate smoothly and without noise at all loads. At the same time, both the engine and turbine run in combination at maximum efficiency through their entire range, and the curves obtained are about as straight as the one in Mr. Stott's test.

4 It will be seen that the flexibility of such an outfit is independent of the mechanical load and the turbine can accomplish practically anything that a high-pressure turbine can accomplish. The gain in power with the synchronous motor system amounts to nearly 100 per cent, due to the fact that the increased rating of the non-condensing engine over what it is at best economy condensing is approximately 20 per cent, which should be added to the 80 per cent additional power given by the low-pressure turbine.

5 Assuming that an engine running under 125 to 130 lb. pressure consumes per indicated horsepower 15 lb. steam, condensing, and 21 lb. non-condensing, and if we divide the additional steam required when running non-condensing by the kilowatts obtained from a low-pressure turbine, we obtain a kilowatt for very close to 12 lb. additional steam per kw-hr. This must be compared with a water rate of say 20 lb. on a high-pressure turbine under the same steam conditions.

6 An interesting point is that the economies obtained for the combined engine and turbine would be equivalent to a consumption of about 11 to $11\frac{1}{2}$ lb. per indicated horsepower in steam engine practice, so that we better the engine economy over what it is at its best point when run condensing, besides producing a kilowatt for less steam than in a high-pressure unit.

7 In the majority of cases the low-pressure turbines have been installed in plants having from 125 to 140 lb. of steam, and the relative gain is just as marked as in the stations carrying 195 lb. of steam and high degrees of superheat.

E. D. Dreyfus. It is interesting to note the remarkable difference in Rankine cycle efficiency between the engines and the low-pressure turbines. This looks as if there is some opportunity for improvement on the low-pressure turbine. Mr. W. B. Flanders of East Pittsburg, has made quite a study of turbine efficiencies, and has found that a high-pressure complete expansion turbine operating with 175-lb. steam pressure and 100-deg. superheat will give the same Rankine cycle efficiency as a low-pressure turbine at the same vacuum and using dry saturated steam.

2 The gain in economy of 13 per cent, as stated by Mr. Stott, is what would be expected when we consider that this unit is operating on dry and saturated steam. I must, therefore, differ with Mr. Rotter, as I know of no complete expansion economies on record that do not agree in the main with what Mr. Stott has brought out. A Rankine cycle efficiency of $70\frac{1}{2}$ per cent on a complete expansion machine, but no turbine performance reaching this degree of efficiency has to my knowledge been recorded in this country. Some have gone as high as 67.8 per cent, but as far as I am able to learn, no record of a complete expansion machine has exceeded 70 per cent.

3 I am very much interested in observing the results obtained with constant and variable exhaust pressure. When this question first came up in low-pressure turbine work, variable exhaust pressure was looked upon with disfavor by some designers and engineers, while others advocated this method because of the better results obtained with it. It is now quite evident that in the neighborhood of 5 per cent additional economy is obtained by running with variable exhaust pressure. As Mr. Stott has stated, it is obvious that unless the piping and apparatus between the engine and turbine are in very good condition, good vacuum will not obtain. I find,

however, that there are a number of low-pressure turbine installations where the low-pressure turbine is coupled with two or more compound Corliss engines with moderately long connections, and they secure

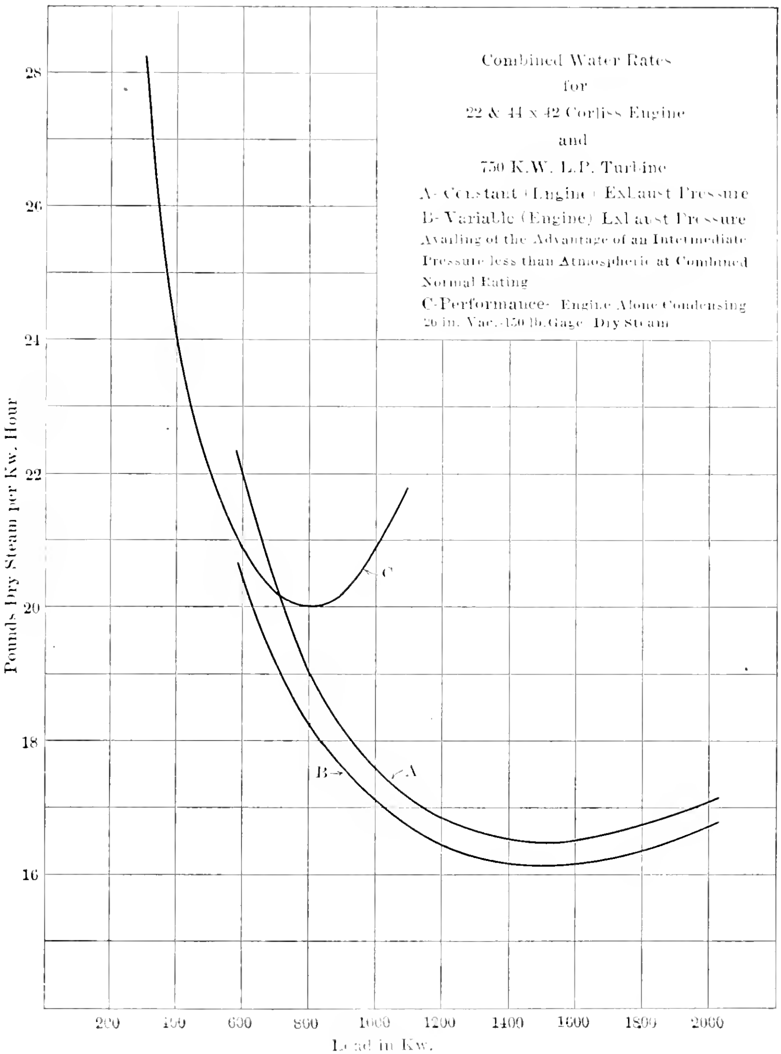

Fig. 1

a vacuum in the neighborhood of 28½ or 29 in. The overall economy, even in the small 1000-kw. units, indicates the same relative gain as

shown by Mr. Stott's results. Fig. 6 and Fig. 7 in Mr. Stott's paper, show the desirability of variable pressure operation on account of looping of the cards.

4 Mr. Stott mentioned in the first part of his paper that the maintenance account of a complete gas-engine plant would be from four to ten times that of a turbine station. To the best of our ability in collecting information and judging working conditions, we do not find it comes up to this factor, and the same thing is true in England according to a paper presented before the Institution of Electrical Engineers on November 17, 1908. This paper was very thoroughly discussed at London, Dublin and Manchester, both favorable and adverse comment being made, but the prevailing opinion seemed to be that the maintenance cost of the complete gas plant would not much exceed that of the steam turbine plant; in fact, the author of this paper claimed it to be the same. When the producer and boiler are considered, there is reason for this statement.

5 Regarding the statement that the results obtained closely approach gas-engine efficiencies, gas-engine coal consumption is usually given for 12,000 to 13,000-B.t.u. coal, but considering 14,500-B.t.u. coal in both steam and gas plants, a material difference of 20 to 25 per cent will easily be obtained in favor of the gas equipment over the most efficient steam machinery.

6 The value of the low-pressure turbine is rapidly bringing about its extensive use in connection with the gas engine, availing of the waste heat of the jacket and exhaust.

Dr. Charles P. Steinmetz. The paper deals with a combination of the low-pressure steam turbine with the induction generator, which, while possibly not familiar to some, is assuming a very high industrial importance.

2 The electrical part of the unit, the induction generator, is not a new type of machine. Its existence was known and its characteristics and behavior investigated and discussed many years ago; but only now has the industry developed in such a manner as to give conditions in which the induction generator is preferable to the synchronous generator.

3 There are two kinds of alternating-current generators: the synchronous generator, which is the ordinary alternating-current machine with which we are familiar, and the induction generator. Constructively, the stator or stationary structure of both types of alternator is practically the same in construction. It comprises a polyphase

winding, in which the electromotive force is induced by the rotating magnetic field, arranged in a laminated structure. The difference between the synchronous generator and the induction generator is in the rotor. In the synchronous generator this is a revolving magnetic field excited by direct current; while in the induction generator it contains a short-circuited winding the same as the armature winding of the familiar induction motor. From this variation results the difference in the production of the magnetic field which by its rotation induces electromotive force in the stationary generator winding. The magnetic field of the synchronous generator is produced by the action of the direct current in the field poles; that of the induction generator is produced by the reaction of the alternating currents issuing from the induction generator. As a consequence the synchronous generator must run in step with the frequency of the alternating system; that is, the rotor must move exactly one pole for every reversal of voltage in the external system. Conversely, the induction generator cannot run in step with the frequency but must always run faster, exceeding synchronism by an amount depending upon the load, so as to cause the induction in the short-circuited windings which produces the currents therein. That means that synchronizing is not required in the induction generator. Furthermore, since the induction generator does not depend upon running in step with any other machine, the possibilities of see-sawing, the so-called hunting which may occur in the synchronous machine, cannot exist with the induction generator.

4 The difference in the production of the magnetic field of the two types of alternating-current generator is the cause of the very characteristic variations in their performance. The magnetic field of the synchronous machine and, therefore, the electromotive force induced in its armature, depends on the direct current supplied to its field winding, but is essentially independent of the load of the machine. It is dependent only in so far as the current output and the power factor modify the field, varying it in the manner expressed by the term "regulation of the machine". The induction-motor field is produced by the reaction of the currents issuing from the machine. The induction generator, therefore, has no regulation and no magnetic field, independent of the voltage at the terminals and the load, but the magnetic field of the induction machine is produced by the reaction of the currents at a value corresponding to the voltage produced at the induction-generator terminals by the synchronous machines connected to the same system. The induction generator

depends in its magnetic field and voltage on the excitation of the synchronous machines in the same system; that is, it can generate only when connected to a system to which synchronous machines are also connected, whether synchronous generators, motors, converters or equivalent apparatus. It has no voltage of its own and cannot operate on a system on which no synchronous machine is connected.

5 The regulation of such a combined system of synchronous and induction machines, therefore, is by the regulation of the synchronous machines operating on the system. Any change of load varies the voltage as it would be varied if this change of load occurred on the synchronous machines in the system. The induction generator is merely a machine feeding electric power into the system but not participating in the voltage regulation or voltage control and having no direct effect on the voltage. While the synchronous machine at open circuit has a terminal voltage, the induction generator ceases to generate and has no voltage at its terminals at open circuit if it is disconnected from the alternating system. In a synchronous generator, even when short-circuited, the electromotive force continues to be induced in the armature windings because the magnetic field is still there as produced by the direct current. The synchronous generator therefore has a short-circuit current which may be many times full-load current, since the total induced electromotive force must be consumed inside of the synchronous generator armature. An induction generator, when short-circuited, has no voltage at the terminals, and therefore receives no current, has no magnetic field, and ceases to generate. In the induction generator when short-circuited, the current dies down from its previous normal value to zero at a rate depending on the resistance and inductance of the internal circuit in just the same manner as the current in a reactive coil, for instance, would die down when the coil is short-circuited and the impressed voltage withdrawn from it. The short-circuit current of the combined system of synchronous and induction generators is therefore only the short-circuit current of the synchronous generators.

6 There results therefrom also the characteristic difference that the synchronous generator can generate current of any character, energy, reactive or wattless lagging or leading, depending on the nature of the system to which it is connected, or the power factor of the supply system; while the induction generator can generate only energy current, and in addition continuously consumes or receives a certain amount of reactive or wattless lagging current re-

quired for its excitation. This latter it receives from the synchronous generators or the synchronous motors and converters in the system. The induction generator, therefore, cannot supply alone a general alternating-current system, for instance, a system of light and power distribution, which requires energy current, as well as reactive, or wattless lagging current; and where a combination of synchronous and induction generators is used, all the lagging current of the system must be supplied by the synchronous generators, and in addition the lagging current also consumed by the induction generator for its excitation.

7 In a system in which there is considerable lagging current, a very large percentage of induction generators is a questionable advantage, since it may throw an excessive overload in current on the synchronous generators, the latter having to supply all the lagging current. On a system requiring no lagging current, or being built to supply lagging current, as rotary converters or synchronous motors, which is the type of system on which Mr. Stott's generators operate and is usual in the large electric power generating and distributing systems, mainly of 25-cycles, there is no lagging current required because the system can be run at unity power factor or even at leading current, and the synchronous motors and converters can be caused to supply the lagging exciting current of the induction generators. There the induction generator is at its greatest advantage.

8 The difference may possibly be described by saying the synchronous generator generates electric current while the induction generates electric power. That is, the synchronous generator supplies electric current to the system whether this current is a power current or a wattless, powerless current; the induction generator can supply only power current and no wattless current. The induction generator, therefore, is the typical converter from mechanical into electric power. It consumes mechanical power and supplies electric power without depending for its supply on field excitation, speed, synchronism or any other feature. It is consequently the ideal machine to float on an alternating-current system, by receiving whatever mechanical power is available and supplied to it in a low-pressure steam turbine from the exhaust steam of reciprocating engines; or in the hydraulic turbine from whatever water power there may be available. It receives the mechanical power and converts it into a proportional amount of electric power, at whatever voltage the system happens to run on, and at any speed, speeding up just above that for which the system is set by its frequency, but with no necessary regulation.

Its straight and simple function is the conversion of one kind of energy to the other, separate entirely from the problem of regulation and adjustment which is thrown over into the synchronous machines in the same system. This is what makes the induction generator a simple and convenient apparatus for cases like that described in the paper and for all others where mechanical power is to be picked up from water powers here and there, and is too small, possibly, to warrant installation of specific regulating mechanism.

Dr. Chas. P. Steinmetz. There is an interesting and somewhat unexpected result shown by the tests, namely that the efficiency was found higher when operating the turbine with varying nozzle pressure than when operating with constant nozzle pressure. The explanation of this is given by the curves in Fig. 13 and Fig. 14. In the latter the efficiency of the low-pressure turbine is higher for constant nozzle pressure, just as expected, but constant nozzle pressure of the turbine means constant exhaust pressure of the steam engine and with this and the varying load, as shown in Fig. 13, the efficiency of the steam engine falls off, dropping from the maximum point at a rate which is so much greater than the gain in efficiency of the steam turbine that the combined efficiency shows an advantage in favor of varying nozzle pressure. This illustrates the fact that the turbine side is much less sensitive to variations of the operating conditions from its best condition than the steam engine is, and that to get maximum economy in the operating conditions the engine should be favored. But that also throws a side-light on one of the reasons why the Rankine efficiency of the turbine is less than that of the steam engine part, because all the unfavorable conditions of operation must be thrown on the turbine side of the cycle to get maximum average resultant efficiency.

2 The gain in efficiency due to the addition of the low-pressure turbine is on the lower side of the cycle, because of the ability of the turbine to expand the steam to a pressure lower than the exhaust pressure of the low-pressure cylinder of the steam engine, an extension impossible with the reciprocating engine. The combined apparatus gains in the ability of the turbine to do what the reciprocating engine is not able to do. This must be kept in mind when comparing the low-pressure turbine and steam-engine plant with the high-pressure turbine plant.

3 The reciprocating engine in general cannot gain by superheat as much as the steam turbine gains, and comparison of the combined efficiency of a saturated-steam reciprocating engine and low-pressure

turbine, with a high-pressure turbine is not quite fair to the latter, because on the high-pressure side. The steam turbine can get an additional gain in efficiency by using superheat which the reciprocating engine cannot to the same extent. In comparing things it is always difficult to get conditions which are equally fair to both types of apparatus because the conditions of proper operation are different in each.

J. W. Lieb, Jr. The author is somewhat optimistic in his estimate that it would be possible to realize as much as 20 per cent of the installation cost from the sale of used apparatus. It would probably be necessary to accept a lower figure, but the result, however, would be still more in favor of the installation of the low-pressure turbines.

2 In the application of the induction generator we have a solution of the problem which combines simplicity of construction and operation with a minimum of installation cost. The induction generator is also of notable assistance in solving the otherwise very difficult problem of handling through the available types of switching gear the enormous energy which might with the usual types of apparatus be difficult to handle in case of a short circuit on the bus bars.

3 The results of the condenser tests are particularly interesting on account of the high rates of heat transference, considerably in advance of the results hitherto attained.

4 The paper is a notable contribution to the economics of power plant engineering and the apparatus described should serve to give a new lease of life to otherwise antiquated engine-driven equipments, although it would be difficult to find another case where the application could be made with such manifest advantages.

Dr. D. S. Jacobus. I visited the plant of the Interborough Company while Mr. Stott's tests were being made and desire to commend most highly the degree of accuracy observed and the general character of the work.

2 The economy of all piston steam-engine installations may not be improved as much as 25 per cent by adding a low-pressure turbine. By examining the paper on tests made at the plant of the Pacific Light and Power Company at Redondo, California, presented to this Society by Mr. Weymouth, it will be found that the heat consumption with a steady load with piston steam engines was about 24,800 B.t.u. per kw-hr. The heat consumption was obtained by dividing

the heat of combustion of the oil burned at the boilers by the net electrical output in kilowatt-hours at the switchboard. The efficiency in the tests of the combined unit by Mr. Stott is 20.6 per cent based on the heat in the steam consumed, and if we take the efficiency of the boilers at 76 per cent, a figure obtainable with oil, the heat of combustion of the fuel burned at the boilers would be 21,800 B.t.u. The difference between Mr. Stott's figures and those obtained at the Redondo plant is, therefore, about 12 per cent. There is a further allowance for the fact that the steam was superheated about 100 deg. fahr. in the Redondo tests and this would increase the figure and make it come more than 12 per cent. It does not seem possible that the introduction of a low-pressure steam turbine at the Redondo plant could ever reduce the heat consumption 25 per cent, bringing it down to 18,600 B.t.u. per kw–hr.

3 The results obtained by Mr. Stott are very close to those which can be secured with large gas engines. The economy of 21,800 B.t.u. could be reduced with proper superheat to about 20,000 B.t.u. per kw–hr., which would be all that could be expected of a producer-gas plant if run on a commercial swinging load with high daily peaks and periods of low power. In a 15 days' continuous test made at the Redondo plant where the load varied daily through a wide range from high peaks to periods where but little load was on the station and where there was a lay-over period of 4½ hours per day, the heat consumption averaged about 25,000 B.t.u. per kw–hr. and it is questionable whether a producer-gas-engine installation could do very much better with a load of this character.

Mr. Schauber. In regard to the statement that the result obtained with the engine-turbine-unit had closely approached the best efficiency obtained in gas-engine practice, I desire to call attention to the installation of four 2000-kw. units at the Illinois Steel Company, operating on blast furnace gas. Records kept for six months under working conditions show a consumption of 15,000 B.t.u. per kw-hr. at the switchboard. When this result is compared with the 21,000 B.t.u. per kw-hr. at the 59th Street station, the comparison is more in favor of the gas engine than the statement made in Mr. Stott's paper.

Dr. D. S. Jacobus. The 15,000 B.t.u. quoted by Mr. Schauber is based on the heat of combustion of the blast furnace gas used by the engines. If there had been a producer this value would correspond

to that computed on the basis of the low heat value of the gas, and where allowance is made for losses through all auxiliaries, this figure would have to be divided by about 0.7 to give the heat units in the original fuel. This would give a much higher heat consumption, say, over 20,000 B.t.u. per kw-hr.

G. R. PARKER.[1] The question often arises as to the smallest size of plant in which a low-pressure turbine can profitably be made, and while no accurate data are yet available, I consider it doubtful if very satisfactory results can be obtained in plants of less than 300 or 400 kw. This is due to the fact that the actual cost of producing power in small installations is not made up so largely of coal as it is in large installations, the labor and the numerous operating expenses constituting a much larger percentage of the cost.

2 A word of appreciation is due Mr. Emmett for the persistance with which he has worked on the problems of the turbine industry, through many early trials and difficulties, until his latest and possibly his greatest achievement, which Mr. Stott has so ably presented. I feel confident that engineering posterity will give due credit to Mr. Emmett.

O. JUNGGREN. The over-all efficiency shown by Test 51, Table 8, is $72\frac{1}{2}$ per cent of the total available energy between the steam entering the engine and the recorded exhaust pressure of the turbine. Test 42 shows an efficiency of 69.6 per cent, and another, 68.7 per cent under different conditions of load and vacuum. A high-pressure turbine, working under the same conditions of steam pressure and vacuum, would probably not give as high an efficiency over such an available range of load as that given by the combined unit, but a high-pressure turbine of approximately the same size could reasonably be expected to give 70 to $70\frac{1}{2}$ per cent at the the most economical load, although fractional efficiencies would not be as good as for the combined unit. A high-pressure turbine would be considerably cheaper then the combined unit and in the near future high-pressure turbines will be made having as high an efficiency as the combined unit, and still be cheaper than a combination of engine and turbine. The vacuums obtained in these tests are quite remarkable and show what can be done in actual practice.

[1] General Electric Co., Schenectady, N. Y.

F. Samuelson[1] said that the field for variable-pressure turbine work, not yet developed in America, has been fully opened up in England and the business is in a very healthful condition. Low-pressure turbines of various types have been employed and all are proving fairly successful. The chief difficulty in the installation of these machines has been to meet the Board of Trade regulations as to constant back pressure on hoisting engines. Accidents are sometimes caused by a drop in back pressure at the engine, due to demands upon the accumulator by the turbine. To prevent this trouble a simple automatic valve has been employed between the engine and the accumulator to shut off the supply from the engine when the accumulator pressure falls to atmospheric. While the regulating valve is closed the turbine is supplied with steam at a reduced pressure. This valve works equally well between the turbine and the accumulator, but the capacity of the latter is much reduced because of the small pressure limit between which it operates. This results in the use of high-pressure steam in the turbine on short stoppage of the engine.

The Author. Refiguring one of the assumed cards (Card C, Table 3, series B) for 100 deg. superheat, we get an actual water rate of 12.9 lb. per h.p. instead of 13.6 with saturated steam, since the missing water and leakage is cut to less than 0.1 of the original value in the high-pressure cylinder. As the missing water in the high-pressure cylinder forms about 0.6 of the total missing water, we shall have 0.46 of the original missing water in this case, or $0.156 \times 0.46 = 0.072$, say roughly 0.08. The B.t.u. supplied per hour $= 12.9 \times 9836 \times 1259 = 159{,}800{,}000$. Radiation and conduction, 1 per cent $= 1{,}598{,}000$ Bt.u.-hr. High-pressure cylinder work $= 5080 \times 2545 = 12{,}940{,}000$ B.t.u-hr.; this leaves 145,262,000 B.t.u. in the steam at high-pressure exhaust, or $\dfrac{145{,}262{,}000}{126{,}900} = 1145$ B.t.u. per lb. At 52.2 lb. absolute, this corresponds to a quality of 96.8 per cent or 3.2 per cent moisture; of this about 2 per cent will be thrown down as receiver drain.

2 The heat thus removed is $0.02 \times 126{,}900 \times 253 = 643{,}000$ B.t.u., leaving 144,619,000 B.t.u. in 124,360 lb. of steam, delivered to the low-pressure cylinder. Low-pressure radiation, $0.01 \times 144{,}619{,}000 = 1{,}446{,}000$; low-pressure work $= 4756 \times 2545 = 12{,}100,$

[1] Turbine Engineer, British Thompson-Houston Co., Rugby, England.

000; leaving 131,073,000 B.t.u–hr., or 1065 B.t.u-lb. which at 13.5-lb. absolute exhaust pressure gives a quality of 91.5 per cent, or 113,800 lb. dry steam available for the turbine. This will give 3,700 kw. on the turbine, which added to the 6710 kw. on the engine gives 10,410 kw. at 12.18 lb. per kw-hr. as against 14.2 lb. with saturated steam. In actual practice the 14.2 rate was cut down to 13.25, and it is reasonable to expect the same sort of result under superheat.

3 The reciprocating engine, when designed for superheat, makes just as good use of it thermodynamically as a steam turbine, but will not stand so much superheat. The point has been raised, that a moisture correction on the turbine is not fair, since without reheating it is not possible to reduce the moisture in the turbine steam to zero. It is fair in this sense, that in order to compare the various water rates on the same basis, it is necessary to reduce all steam conditions to a standard and that standard is naturally dry steam. Moreover, when the moisture gets as low as 1 per cent or 2 per cent the correction is negligible in amount, and the curve of corrected water rate is substantially true. It is quite possible that a separator can be designed that will take out all but 0.2 or 0.3 per cent of moisture; and in this case the correction justifies itself.

TOPICAL DISCUSSION ON THE RELATION OF THE STEAM TURBINE TO MODERN CENTRAL STATION PRACTICE

By G. R. Parker[1], Schenectady, N. Y.

Non-Member

In regard to turbine installations the question is often asked as to what are the most economical steam conditions, i.e., initial pressure, vacuum and superheat. While there is much discussion on these points, the present American practice is becoming reasonably standardized. As to vacuum, there is no question that it is worth while getting the highest obtainable, provided an ample supply of condensing water is available. Twenty-eight inches or even higher vacuum can readily be obtained with modern condensing apparatus. Steam pressures vary from 150 lb. gage to 250 lb. gage. In the smaller and medium sized plants probably 150 to 175 lb. is about right, while in the larger ones 175 lb. to 250 lb. should be

[1] General Elec. Co., Schenectady, N. Y. Discussion given at St. Louis December 11, 1909.

employed. The arguments for and against superheat are numerous, but the consensus of opinion is inclined to favor it to a reasonable degree, at least in the large and medium sized plants. Superheat ranging from 50 deg. fahr. to 250 deg. fahr. is in common use.

2 Modern steam-turbine practice has advanced so rapidly in the past few years that quite startling changes have been effected in some of the original turbine stations. Improvements in details of construction and increase in speed have greatly reduced the size and weight per kilowatt. About six years ago the first large turbines were installed in the new Fisk Street station of the Chicago Edison Company. The first three machines were vertical 2-stage machines of 5000-kw. capacity, and the fourth, installed somewhat later, was of the same capacity but of the 5-stage type. Within the last year these four machines have been removed and replaced by four vertical machines of 12,000-kw. continuous capacity each. These occupy no greater space than the original machines, and no increase in the number of boilers supplying them was necessary. The Fisk Street station now contains ten similar machines of 12,000-kw. each. The Quarry Street station of this same company at present contains three vertical machines of 14,000 kw. each and three more will be installed during the coming summer. The economies obtained in these plants are reflected in the rates the Commonwealth Edison Company is able to make its consumers.

3 A somewhat similar evolution is now under way in St. Louis. In 1905 the Union Electric Light and Power Company installed two 5000-kw., 500-r.p.m., 25-cycle, 6600-volt, vertical turbines. Later two more 5000-kw. machines were added, but with 60-cycle, $\frac{2300}{4000}$-volt generators. The present plan, which is now well under way, is to replace all four machines with other turbines of 12,000-kw. capacity each.

4 The natural question is, can it possibly be a good business proposition to throw out four large turbines which have been in use only three or four years? That the answer was affirmative was due to three principal considerations.

a The larger machines could be installed without increase in floor space.

b The improvement in economy represented an annual charge which if capitalized would more than pay for the additional investment.

c Practically no new auxiliary apparatus or station piping would be required.

That these considerations were based on correct assumptions has been amply demonstrated. The first 12,000-kw. turbine has now been in commercial operation for several weeks.

5 In making this installation not only was it found possible to utilize the original foundations, but even the base of the old turbine, which also constitutes the exhaust chamber and step bearing support, was utilized in building the larger machine. It was, therefore, not necessary to remove this base from the concrete, or to break the connection to the condenser. The increase in capacity means that in this portion of the station the kilowatts per square foot of station has been more than doubled. Even the original four 5000-kw. machines were placed unusually close together and when the remaining three are replaced by larger machines it seems probable that the turbine portion of the station will show a greater output per square foot than any other station in this country.

6 On the question of economy, it would seem that we are approaching very close to the limit with the latest turbines. There are certain losses inherent in the turbine, such as those due to radiation, to wheels revolving in atmospheres of different densities, and the friction of the steam on the blades, which make it doubtful if we shall ever succeed in getting an efficiency of more than 75 per cent. Rapid progress toward this mark has been made in the last few years, largely due to better bucket design, until the latest machines in the Union Electric Light and Power Company's plant have a theoretical economy of 66 per cent.

BALL-BEARING LINESHAFT HANGERS

By Henry Hess, Published in The Journal for May 1910

ABSTRACT OF PAPER

The paper gives in detail the actual and relative first cost of a lineshaft installation, consisting of hangers, boxes, shaft, pulleys and belt, transmitting 40 h.p. at 200 r.p.m., on plain bearings, then on ball bearings, at 600 r.p.m. The latter installation costs less by $117.08, a saving of 21 per cent in first cost; this carries with it an annually recurrent saving of $36.90 in power.

The hanger and ball bearing are described and illustrated..

DISCUSSION

Frank B. Gilbreth. Is there any information available regarding a comparison of the manner in which concrete buildings and so-called mill buildings affect ball bearings? Nearly all engineers practicing in the construction of concrete buildings believe that the lack of vibration in this type of building lowers the cost of maintenance of lineshafting, hangers, bearings, and similar machinery.

Charles Whiting Baker. One argument against concrete buildings is that the dust raised is injurious to the working parts of machinery. It would be interesting to know whether ball bearings will stand that dust better than plain bearings.

2 Where it is desired to dispense with lubricants, at least so that there shall be no dripping, does the ball-bearing lineshaft solve the difficulty?

Frank B. Gilbreth. If the point about dust in concrete buildings is to be raised, they should be separated into two classes, those with wooden floors and those with concrete floors. There cannot be any dust in a concrete building with a wooden floor.

2 I would like to know what method is best in a concrete building for holding a lineshaft hanger to the ceiling; not only a ceiling with

ribs, but also of the flat type. Hangers are usually of two types, those that can be located before the building is erected and those put in afterward. Concrete men have studied that subject a great deal but do not feel that they know the needs of the hanger men or of the bearing men.

F. W. Dean. It is quite evident that wooden mill buildings must have the shafting lined up frequently to get minimum friction, but a concrete building is supposed to preserve its alignment after it is finished and set. There is great opportunity for the diminution of friction in mills. It is not always a question of bearings, but sometimes of the arrangement of driving machinery. In a mill where the friction load was 42 per cent of the running load, an examination showed that it was due to a great number of quarter-turn belts.

J. Sellers Bancroft. I wish to correct an error in Mr. Hess' paper where he ascribes the invention of the ball-and-socket hanger to Mr. Bancroft, one of the oldest members of the Society. The invention was made about 1848 by my father, Edward Bancroft, who died many years before the society was organized.

G. N. Van Derhoef. In Par. 4 of this paper, Mr. Hess referred to the early type of hanger with ball-and-socket plunger screws and mentioned the stress of modern conditions as leading up to modern hangers with very little machine work. These conditions may have had some bearing, but experience has shown that extensive machine work is not necessary. Carefully fitted machine parts at the end of the plunger screw are unnecessary because the vibration of the shafting will level the bearing. After the box is in its proper position, it will stay there until the settlement of the building requires realigning of the shaft. With the ordinary hanger box, the pressure required at the end to bring it into position is very slight. Accurate machine seats, however, are proper and an absolute necessity in the case of ball bearings, where a single row of balls is used, because there is no leverage, the balls being in direct line with the plungers. The friction must be reduced to almost nothing or the bearing will tend to cramp on the shaft.

2 In his list of desirable features for hangers, Mr. Hess mentions horizontal adjustability of the box within the hanger body. This is rather a mooted question on which are two widely different beliefs.

One is that the box itself should move across the hanger or frame and the other is that the hanger body itself should be used as the movable body. Anyone who designs a four-point hanger will soon find difficulties in moving the box across the frame without introducing complications.

3 In regard to neatness of general outline and conformity to modern machine design by substituting box sections for ribbing, neatness is desirable, but the substitution of box sections for ribbing is unimportant. The amount of metal necessary in any cast-iron hanger frame to take care of vibration enables almost any shape to be used which will have the requisite strength. It is rare for any cast-iron hanger to break under load.

4 Fig. 1 shows the box itself carried by screws at the side, a construction similar to that in what is commonly known as the Boston hanger, which has been used for a great many years in the eastern part of this country. The defect of this type is that it carries the weight of the box directly upon the side screws and its swiveling in that way is hard on such small bearings. To get horizontal adjustment the box must be shifted out of the center line of the vertical plunger screws, which is bad practice; or the vertical plunger screws must be shifted at the same time as the box. If the vertical plunger screws are left in a fixed position the center of the box is shifted out of its correct location in line with the axis of the main screws. If the screws are shifted they must all be loosened and tightened up again every time the box is shifted sideways, Even then it is likely to be out of line vertically. Mr. Hess has approximated the solution of the problem by using a great deal of machine work and it is really necessary if these complicated adjustments are wanted. This type of hanger frame is needlessly expensive for ordinary conditions.

5 Mr. Hess mentions the advantage of running a shaft at high speed, say 600 r.p.m., and makes the statement that a shaft with ball bearings can be run at a higher speed than a shaft with plain bearings, but not long ago I saw a number of shafts 80 to 100 ft. long and about 2-$\frac{11}{16}$ in. in diameter, with plain bearings, running successfully at 700 r.p.m. The shafting and hangers were ordinary materials bought out of stock, without the seller knowing anything about the speed at which they were to run.

Harrington Emerson. For miscellaneous and scattered shops the power plant which is dependent on coal, cheapest to install and maintain, as well as cheapest and most reliable to operate, consists of:

a A gas-producer plant near a side track.
b Gas transmission by mains.
c Individual gas engines on main lineshafts running 400 to 600 r.p.m.
d Leather belt transmission to jackshafts and machines.

2 I therefore welcome ball bearings on lineshafts as an important aid to this form of power transmission. I much prefer the installation outlined to turbo-electrical generation, wire transmission and motor drives.

The Author. If the dust from a concrete building is allowed to get into ball bearings they will be destroyed just as any other bearing would be under these conditions. The problem is to keep the dust out, and in the case of ball bearings it is an exceedingly simple matter to keep foreign matter out and the lubrication in under the most adverse conditions. This is done by extending the bearing box on each side enough to allow for two additional grooves in addition to the one usually employed. The two outer grooves prevent the dust from getting to the bearing and the third or inner groove traps the oil or other lubricant and drains it back to the bearing. Even in a marble plant, where the dust is considerable in amount and a more efficient cutting material than emery, no trouble has been experienced with ball bearings and the lubricant is renewed but once each year. The same device has been successfully employed in submarine dredges under a 40-ft. head of water to keep the water out of the bearing and to prevent loss of the lubricant.

2 The Thompson Meter Company in Brooklyn occupies a concrete building and is equipped throughout with ball bearings with no trouble from the concrete dust. Even in mills where there is a considerable quantity of lint floating in the atmosphere it never gets into the bearings.

3 Ball bearings were first applied to steam railroad passenger cars in Europe and the first cars have now run over 600,000 miles. They were originally charged with pale yellow vaseline and after they had run 140,000 miles I found it still pale yellow in color. This indicates that there has been no deterioration in the lubricant and that the closure of the bearings was effective.

4 Regarding Mr. Jackson's question as to the advantages of ball bearings at high speed, it is manifest that the plain bearing with heavy load is much more difficult to lubricate and must be more carefully looked after to insure sufficient lubrication than is neces-

sary with the ball bearing. There is a general impression that the ball bearing may be run without any lubrication whatever, but this is not true. If they could be made of absolutely incompressible material and absolutely true balls and races could be produced they would probably need no lubrication. Furthermore, with high-speed lineshafting using either plain or ball bearings, smaller pulleys can be employed, requiring a smaller drop in the hangers. The loads on the bearings are therefore lighter and the belts are narrower and less expensive.

5 The ball bearing which is loaded to three or four times its rated capacity will show a slight heating, hardly noticeable to the touch. The amount of excess pressure put upon such a bearing by a large shaft that has gotten out of alignment is too small to show itself by heating. In fact, one of the troubles with users of ball bearings, particularly where thrust bearings are used, is the failure to realize that the friction is so little that even when the bearing is greatly overloaded that fact does not manifest itself in greatly increased resistance, as is the case with plain bearings. A bearing which is so overloaded that it shows additional resistance to turning or an appreciable rise in temperature is so seriously overloaded that it will soon be destroyed.

6 The question as to the relative frequency of alignment in mill buildings and the more rigid concrete buildings carries its own answer; the more rigid a building the less frequent will it be necessary to realign. When the building moves, the bearings have to be realigned. The difference between plain and ball bearings is that the former, in case of a considerable shift, will squeal and require attention, while the latter remains quiet, does not heat and its life is not even affected, because it has a sufficient margin to take care of such overloads. Nevertheless, such shifting should not be neglected because the work done in bending the lineshaft has to be paid for as power consumed. The proper thing to do is to put bearings in a hanger in which they cannot shift and thereby realize the benefits of rigid hangers and bearings.

7 The mill mentioned by Mr. Dean as having a 40 per cent friction load was probably a textile mill. In such mills the power is so large an element of the total cost that it is usually looked after very carefully. The shafting is generally well aligned, the hangers, bearings, etc., all receive close attention and frequent oiling, and consequently the best results as to low friction losses. In most industries a totally different state of affairs prevails. In machine

shops, for instance, the friction load of lineshafting and countershafting almost always exceeds fifty per cent, and in many cases it is as high as sixty-five and seventy per cent. In the Utica plant referred to, the substitution of ball bearings for plain bearings would have reduced the friction losses 60 to 90 per cent.

8 It has been stated that lineshafts with plain bearings were running satisfactorily at 700 r.p.m. There is no reason why such shafts cannot be run at 1700 r.p.m. except for the necessity of far greater care in maintenance and the relative friction loss. The ball-bearing lineshaft can be run at 600 r.p.m. without attention from one year's end to another; it is not even unnecessary to realize it, except for the power loss in bending the shaft. The limit of speed is not set for the ball-bearing lineshaft by the bearing, but by the requirements of the machine to be driven. In many cases they run at 17,000 r.p.m., but 600 r.p.m. is about the highest practicable for the average machine shop countershafts, where the pulleys must not be too small to secure sufficient belt contact.

9 The point was raised against the type of hanger described in the paper that when the box is shifted from the center of the hanger in the realigning, the shaft is out of line with a vertical drawn through its two supports. If the belts from the lineshaft were running vertically downward, the argument would be a valid one, and in such a case it would be desirable tohave the bearing centered in its support and coincident with the line of belt pull. Ninety-nine per cent of the belts, however, are run much more nearly horizontal than in any other direction. Those that do not run absolutely horizontal runs at some angle, usually but slightly deviating. This puts the pull in line with the horizontal support of the box and normal to the vertical supports. Therefore a cross-aligning movement of the box is of no moment. The principal requirement is that the hanger be sufficiently stiff. In the one described in the paper the yoke is of cast iron and the two vertical members cast with it have a considerable diameter and therefore sufficient stiffness.

AN IMPROVED ABSORPTION DYNAMOMETER

By Prof. C. M. Garland, Published in The Journal for March 1910

ABSTRACT OF PAPER

This paper describes a type of eddy-current dynamometer adapted for the absorption of power given out by motors under test, with an enumeration of the conditions that an absorption dynamometer should fulfil, illustrating the advantage of this machine.

The dynamometer consists of a copper disc revolving between the poles of an electro-magnet. The power absorbed is utilized in the generation of eddy currents in the disc, which short-circuit among themselves and produce heat, which is carried off by circulating water. The change in load is effected by a rheostat in series with the exciting coil. Attention is drawn to the flexibility of the design and the adaptability of the machine to both large and small powers.

DISCUSSION

C. M. Allen. This paper describes a unique and interesting form of absorption dynamometer, but practically all of the claims brought out in the paper are applicable to and descriptive of the Alden absorption dynamometer. The Alden absorption dynamometer never binds or seizes if it is properly set and operated, and with the automatic valve attached, the internal friction, temperature, wear, etc., have no effect on its keeping balanced steadily, holding the load constant for an indefinite period of time. It accurately indicates the load from full capacity practically to zero, merely the friction of its bearings is indicated, and I do not see why the dynamometer described in this paper would not have the same amount of initial load. The regulation of the load on the Alden brake is positive, and although not instantaneous in its true sense, the full load can be put on or off as quickly as the valve can be opened or closed. The Alden brake also requires very little attention if properly set up and operated. The automatic valve entirely does away with any hand manipulation, keeping the load constant for hours without any attention. For a given amount of horse power, the Alden brake probably takes up as little room as the one described in this paper, because the brakes can

be made with multiple discs. They run as quietly as any ordinary oil bearing and are as free from splash of oil and water. They are also readily changed from one prime mover to another. They can either be mounted on a portable stand, as the one described in this paper, or they can be put on the overhanging end of the engine shaft. The amount of cooling water ordinarily used would be a little greater with the Alden brake than in the electrical dynamometer described in order to keep the temperature of the machine lower for the best operation; but for small machines running at high speeds, it is perfectly feasible to run the cooling water hot enough to make steam.

2 We have used Alden dynamometers in the laboratory of the Worcester Polytechnic Institute for a good many years, ranging in size from discs 6 in. in diameter up to 34 in., in horse power from $\frac{1}{100}$ up to 150, and in speed from 0 up to 3000 r.p.m., and we are convinced that they are reliable, accurate and comfortable machines to work with. These brakes have always done the work demanded so exceptionally well that the writer has taken up the testing of large water-wheel units after installation. Further particulars concerning the action of these large dynamometers are given in the paper on The Testing of Water Wheels after Installation, published in The Journal for April.

3 The Alden dynamometers are used extensively in a large number of engineering schools of this country and abroad. They are also used by a great many of the largest automobile manufacturers in this country for testing their engines before installation in the cars, and in some cases after installation by connecting a dynamometer to each end of the rear axle.

4 These remarks concerning the Alden dynamometer are entirely unnecessary for those who are familiar with it, but were written for the benefit of those who are still looking for a reliable and accurate prony brake.

The Author. I am very glad that Professor Allen has brought out the advantages of the Alden brake as compared with those claimed for the dynamometer described in my paper. The Alden dynamometer fulfils very nearly the specifications outlined for the magnetic dynamometer. However, I believe that the latter has the advantage of requiring less attention and about one-tenth of the weight of water, or in some cases much less; also of the elimination of mechanical friction which renders seizure of the rotating with the stationary parts a very remote possibility. While this is well taken care of in the Alden

brake, yet if the temperature of the water rises so that the lubricating oil becomes less viscous between the discs there is always present this danger. I further believe that the regulation or the changing of the load requires a greater amount of attention. The magnetic dynamometer, if properly constructed, operates as steadily as an electric motor and is, without doubt, the ideal machine in so far as operation is concerned.

THE ELASTIC LIMIT OF MANGANESE AND OTHER BRONZES

By J. A. Capp, Published in The Journal for March 1910

ABSTRACT OF PAPER

At a stress but little above the elastic limit, or the limit of proportionality of stress to strain, mild and medium steels show a characteristically sudden breakdown, such that during an appreciable interval the specimen stretches without increase of load. This point, called the "yield point", is marked by a jog in the autographic elastic curve, and is indicated by the dropping of the beam of the testing machine and the slipping of the points of dividers held in bench marks on the specimen. The paper deals with the elastic curves of brasses and bronzes, which show no such break or jog, but characteristically are smooth curves, substantially straight at first and gradually bending over at an increasing rate as stress increases. Hence the locating of a so-called yield point, in testing bronzes or brasses by commercial methods, is entirely a matter of the judgment of the operator, and the point reported bears no definite relation to the elastic limit or limit of proportionality as indicated by the elastic curve.

DISCUSSION

S. A. Moss. The point has been raised as to whether we are able to find the limit of proportionality in bronzes by the old steel method and I would like to raise the additional point, as to whether we are interested in the limit of proportionality at all. The engineer is interested in the permanent set, which may not be connected with the limit of proportionality in any way. It would be a good thing if we confined our attention to this set, and in making tests on materials almost wholly remove the load after each application, measure the permanent set, apply a greater load, remove it almost wholly, and again measure the permanent set. In this way we could make a curve of permanent set, and need not consider the stress-strain curve. Such curves are of the shape of the usual stress-strain curve, with quite a bend. The place where the bend begins should be defined as the beginning of the elastic limit, which is of much more interest to the engineer than the limit of proportionality or the yield point with which he is usually concerned.

2 This cold-drawing process, or application of stress for a second

time, is somewhat complicated. After material has once received a permanent set, it will not receive as great a one the second time. This must be taken into account and the place found where the appreciable permanent set begins after the second application of load. That necessitates applying and removing each load twice before measuring the permanent set.

F. W. Dean asked if there was any evidence to show that a piece of steel left to itself for a time regained any of its original qualities.

The Author. Mr. Howard at the Watertown Arsenal, has recently repeated tests on bars which were overstrained a great many years ago, and have since been laid aside to rest. The tests are not entirely completed, but there seems to be evidence that if the overstress is not so great that the particles have been definitely torn apart and set up in new arrangement, there will be almost an entirely complete recovery, in which the chances are that the original limit of proportionality will have been raised to a point between the original value and that of the overstrain.

2 Dr. Moss's statement with respect to the location of what we might call the first permanent set point is pertinent. It is perhaps a happy coincidence that in most of the materials commonly tested for engineering purposes, the first permanent set point and the limit of proportionality very nearly coincide. Taking into account the very long time it takes to conduct a test to determine the first permanent set point and the difficulties in making sure that the lower load selected as the zero point is always exactly secured, there is a justification for abandoning that method of test in favor of plotting the elastic curve, and getting the limit of proportionality. The points are not so far apart that the engineer is not warranted in basing the safe load on the limit of proportionality instead of on the first permanent set point.

3 Dr. Moss had mentioned as possible a material which does not show any permanent set until the stresses have been carried well out on the curved portion of the elastic curve. Cast iron is apt to be such a material. There is practically no straight line portion on the elastic curve for cast iron, and yet it is difficult to measure any permanent set when testing, even the ultimate elongations being small and difficult to measure. Several persons have reported as much as one-quarter per cent of elongation in eight inches, which is, of course, very little. The relatively more brittle metals usually test as high as four or five per cent, and tougher metals as high as forty per cent.

4 A jog in the stress-strain curve is characteristic of all the mild or untreated steels, and it is also true that overstressing eliminates it. That is shown in testing cold-rolled steel or steel wire, the extreme case of cold-drawn steel. Steel wire is obtained by a controlled stressing of the material beyond its elastic limit by drawing it through a die, which to a certain extent controls the amount of the permanent set and of the overstressing.

5 The real object of testing is to determine the characteristics of a material so that one may decide what shall be safe stresses in any structure, taking into account the elastic properties of the material, its ability to stand up under repeated or alternating stresses and other similar conditions. Usually such safe loads are a certain proportion of the elastic limit. If, however, the elastic limit is determined by erroneous tests to be double its true value, any calculation based on such data is utterly unsafe.

THE TESTING OF WATER WHEELS AFTER INSTALLATION

By Prof. C. M. Allen, Published in The Journal for April 1910

ABSTRACT OF PAPER

Brake tests of water wheels after installation have been in growing demand for the past few years. This paper describes the brake and its use in connection with the testing of large water wheels, with a few suggestions as to why a brake test is advisable after installation. Several tests are given showing the results in the form of curves of poor, good and exceptionally good water-wheel settings, with sketches of layouts. The efficiencies of large bevel gears, such as are used in large vertical drives, were determined by a brake test on both the horizontal jack shaft and the vertical wheel shaft, making a sufficient number of tests to insure reliability. The proper setting of a water turbine is described in a general way.

DISCUSSION

R. A. Hale.[1] The Holyoke testing flume has furnished much valuable information in regard to the efficiency of wheels, but it has always been apparent that differences in efficiency occur, depending on the conditions of installation. No absolute knowledge can be obtained without an actual test of the wheels in position to drive the mill. The example cited by Professor Allen of a pair of wheels placed so close together that the discharges interfere is common where space is limited and the quarter turns are crowded together at the expense of efficiency. Other undesirable conditions may exist, such as high velocity in the penstock and a small wheel case leading the water in a much disturbed condition to the wheel. Another fault sometimes occurs in not having sufficient space in the raceway or pit under the wheel for the discharge, causing obstruction and loss of power.

2 A most important and often-neglected point in connection with wheels is the proper design of the draft tubes connected with the

[1] Principal Assistant Engineer, Essex Water Power Co., Lawrence, Mass.

discharge. They are often placed in some available space without regard to its size or direction. With wheels set on a horizontal shaft, as is customary at the present time when possible, long tubes are necessary. Sometimes these are installed with a uniform diameter and set vertically so that the water striking downwards on the bottom of the pit has to turn a right angle to leave the wheel. Examples of this method exist in what are considered model mill plants.

3 The most efficient forms of draft tubes illustrated in Professor Allen's paper are those shown at an inclination and discharging in the direction of the current, with a gradually enlarging area of tube from the inlet to the outlet. The velocity of the water leaving the wheel outlets is necessarily very high and with the enlarging area the velocity may be reduced, with a decided gain in the head derived from the reduction in the velocity of the water leaving the outlet of the tube. The amount of inclination of the tube from the vertical must be considered, and one case comes to mind where the inclination is such that when the wheels are run at part gate a large percentage of the effect of the draft tube is lost, as shown by the reading of the vacuum gages at the center of shaft. At full-gate opening a loss exists, but is not so serious. The inclination of the draft tube to a vertical line through the center of the shaft in this particular case exceeded 60 deg., and was set to avoid removing considerable masonry. Although no fixed rule of inclination or curvature can be stated, it would appear from various cases noted that the inclination should not exceed 45 deg. and all abrupt changes in direction should be avoided. The outlet of the draft tube should be submerged sufficiently to prevent air from entering and destroying the vacuum and the elliptical form of outlet as indicated in Professor Allen's sketch provides area without the necessity of deeper excavation, which a cylindrical tube would require. At Lawrence a slight modification has been used to obtain additional area by building in a rectangular concrete outlet extending beyond the end of the draft tube. It has been the practice to ascertain the height of water as compared with the tail race and, when unreasonable loss is indicated, a leaky packing box or some similar condition is looked for. These gage readings would correspond to the indicator cards of an engine in regard to discovering losses.

4 Our theoretical knowledge of draft tubes, however, is very limited, and the necessity exists for a series of experiments embracing various forms and inclinations of draft tubes, which would give exact knowledge of the best form and the conditions in which they should

be used. A series of vacuum gages attached at various points on the tube, or a water column shown by a glass tube, the upper end connected with the draft tube and the lower end with the water in the tail races, would show what conditions exist in various portions of the tube. A series of experiments in connection with brake tests on a wheel at the same time would add much to the knowledge of the efficiency of wheels and draft tubes.

5 One other point that suggests itself is the importance of the relative velocity of the wheel, or the ratio of the velocity of a point on the circumference of a wheel, to the velocity due the head of water.

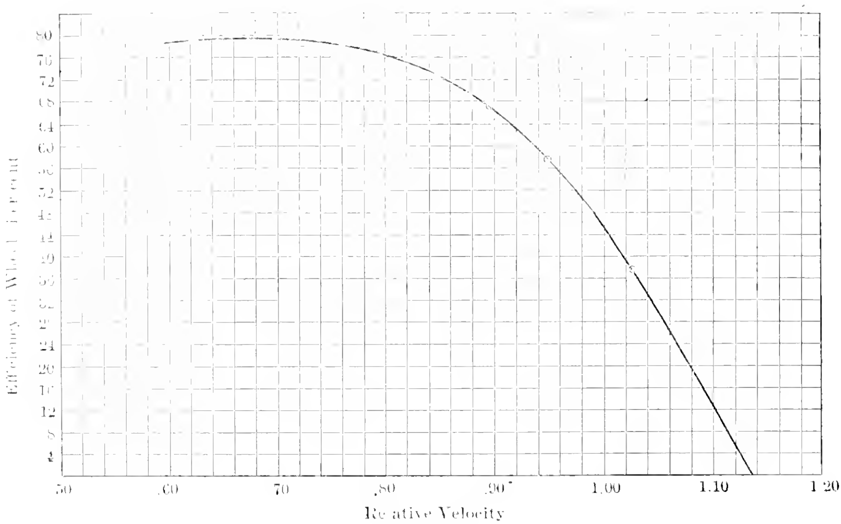

FIG. 1 VARIATION IN EFFICIENCY WITH RELATIVE VELOCITY

By reference to the curves given by Professor Allen (Fig. 14), it will be noticed that there is a speed where the maximum power is obtained, and a falling off in each direction from this maximum. It is important, therefore, to select a wheel that shall run at the proper speed to give the maximum efficiency for the head under which it is to act. For this purpose the average head that exists most of the time would be selected. Under ordinary variations the percentage of loss is not excessive, but when great variations occur the efficiency is reduced materially with a constant speed.

6 Fig. 1 shows experiments made at the Holyoke testing flume on a 48-in. McCormack wheel, the horizontal scale representing the rela-

tive velocity and the vertical scale the efficiency of the wheel by the brake test. It will be observed that from 60 to 75 per cent there is but slight variation in the efficiency due to the change in the relative velocity. As the relative velocity increases beyond this point the efficiency falls rapidly. When at a relative velocity of 1.02 the efficiency is about 39 per cent, and at about 1.13 relative velocity there would be no efficiency. Such a curve is characteristic of this type of wheel.

7 Fig. 2, the practical application of this curve, shows the net horse

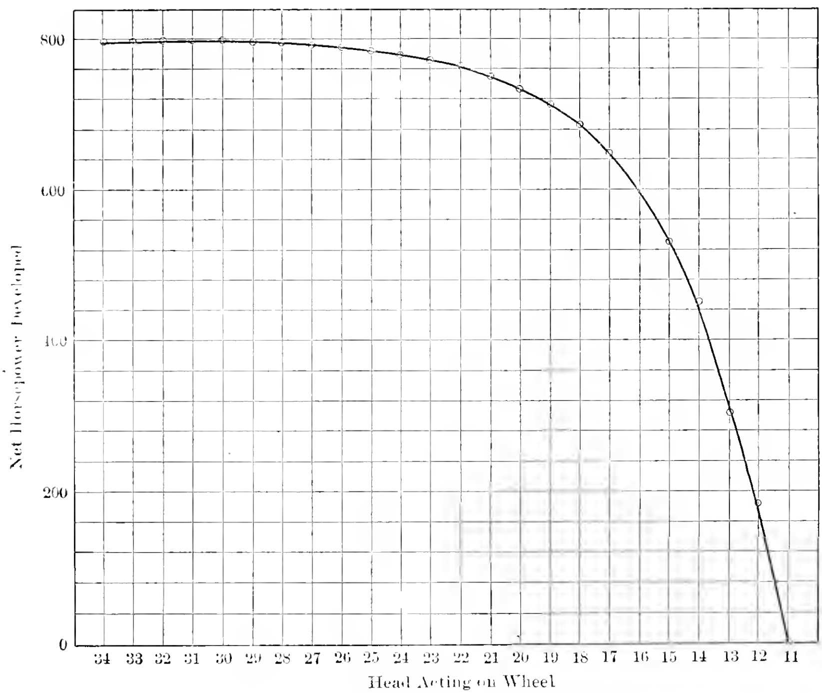

Fig. 2 Variation in Power Developed with Change in Head

power available from 1000 gross horse power of water with heads from 34 ft. to 11 ft., assuming the speed of the wheel constant and the gate to the wheel wide open. The efficiency of the wheel is assumed as that given by the Holyoke test at full gate. With wheels designed for about 34 ft. the best results are obtained. With a decrease in fall to 20 ft. and the same speed, a falling off of about 50 h.p. occurs, and at 11 ft. there would be no power derived from the wheel. The conditions could not occur on one wheel as the quantity would de-

crease with decreased fall, but there would be a series of wheels added as the head decreases. Reduction of head due to freshets producing back water occurs on all streams, causing loss of power, even with a large quantity of water available.

8 The quantity of water is also affected by the speed of the wheel, and in computing tables of discharge should be taken into account. The examples shown by Professor Allen of discoveries of loss of power by brake tests should be convincing proof to manufacturers and users of power that tests of this character are essential for actual information as to the efficiency of a wheel plant.

9 In connection with the two wheels set on a horizontal shaft and discharging into one draft tube, the results found by Professor Allen are very interesting. The discharge is affected to a considerable extent by the amount of opening of the wheel gates and whether or not both wheels are running. I have had occasion to measure the discharge from a pair of 36-in. Hercules wheels thus situated and at fifteen different gate openings on each wheel. The wheels were run together and then separately, and the combined discharge of the two wheels running together was considerably less than that obtained by adding the discharges when each ran separately. This showed that the confliction of the water discharged with both running reduced the amount that could be discharged. As wheels are run separately in this manner, it would appear that tests on this condition would be desirable.

10 In connection with the measurement of water very excellent results can be obtained under suitable conditions with the current meter. We have made various tests with the current meter, at the same time measuring the quantity of discharge over a weir under excellent conditions (quantities of 400 cu. ft. per second) with variations as low as 3 cu. ft. between the current meter and the weir. Excellent results have also been shown under conditions not as favorable. With the current meter attached to a pole instead of a line, correct results are more certain, and I should have entire confidence in the meter under the fair conditions which exist in flumes and raceways in connection with the discharge of wheels.

John Castlereagh Parker. The Holyoke tests are very excellent for standardizing wheel practice, but they cannot in the nature of things give exact information as to exactly what the wheel is going to do in the power plant. A great deal of the performance of a water wheel is dependent on the nature of the setting, the intake works

and the draft tube. Those are conditions which cannot be duplicated in any standard laboratory, which the Holyoke plant is in all essentials. The Holyoke flume is not, if I understand the construction of a testing plant aright, adapted to tests on wheels of special shapes. Most of the larger wheels of today are designed for use either as vertical-shaft or horizontal-shaft machines, with spiral casings. The Holyoke flume was designed for and is most applicable to the old barrel type casing. Practically all of the most modern wheels, in the larger sizes at least, are made with spiral casings. Field tests must be made if we wish to know what such wheels will do.

2 Another important value in the field tests is that they enable us to make checks from time to time on the performance of the wheels to find whether the runners are deteriorating. The complexity of the grooves in a turbine runner is so great that it is practically impossible to check the wear, although it might very appreciably cut down the efficiency.

3 Without intending to disparage the use of the dynamometer, I am inclined to question whether it should be designed as a substitute for electric loading. We recently tested three 16,000-h.p. turbines by the electric loading method, which we have found simple and easy to apply.

4 The electrical method provides a considerable degree of security from some of the vicissitudes that Professor Allen has spoken of in connection with his tests. When things go wrong it is simply necessary to close the gates without any worry as to what will happen with the dynamometer. The profession, however, owes a debt of gratitude to the man back of the development of a brake which will enable us determine the efficiency of turbines in those plants where the simpler electrical loading is not available. The paper industries require direct drive and a great many privately owned plants are used to operate manufacturing establishments, such as textile mills, for instance, where power is taken directly from the shafts of the turbines to the shafts in the building. In such cases it is convenient to have a simple and reliable method of getting the loading on the machines.

5 I want to express my accord with what Professor Allen has said in regard to the reacting effect of the design of housings and draft tubes on the efficiency of water wheels. The practice in this country and a great deal of the practice abroad has been vicious in the extreme, in that we have not attempted to put into the design of conduits, housings, and draft tubes even the most elementary hydraulic princi-

ples. American practice has lagged decidedly behind that on the other side in this respect. The old barrel type of housing is execrable, so far as developing efficiency is concerned, especially in the low-head plants, where it has been used almost entirely. We are asking the water to turn at right angles, to change the velocity of flow in passing from sudden contractions to sudden expansions, and to do all sorts of things that no stream of water could readily do.

6 The field tests have no direct bearing on the design of runners. I think the tests made at Holyoke and in the field, however, have helped to improve American runner design and they still have the great advantage of emphasizing the importance in our works of adequate design for leading the water up to and away from the runway. We are indebted to Professor Allen for what such tests as he is conducting will do in that direction and for bringing us to select our wheels more intelligently for the particular heads for which they are to run.

Prof. Dwight Porter.[1] The most desirable test to apply to a turbine is one by which the input and output of power shall be accurately determined under the conditions of final installation. Professor Allen is rendering great service to users of power and to turbine builders by the work he is doing, and it should have generous recognition.

2 Of the three main factors underlying the question of turbine efficiency, namely, volume of water fed to turbine, head acting, and horse power developed, it would seem that the latter two should generally be capable of determination with satisfactory accuracy. Under conditions which sometimes exist at a power station the measurement of the volume of water, however, may be open to material error, and the value of that error seems less easily assignable than at a standard testing station. The pair of wheels referred to in Par. 38 showed an increase of 130 h.p. at 195 r.p.m., when tested after installation, as compared with the amount computed on the bases of Holyoke tests made at a lower head. This means an increase of efficiency of between four and five per cent for the 2600 h.p. developed; but it is easy to conceive of circumstances in which an improper weir coefficient or an imperfect current-meter measurement might lead to an error of at least half that amount.

3 So long as the testing of wheels at a commercial station is

[1]Professor of Hydraulic Engineering, Massachusetts Institute of Technology, Boston, Mass.

common, where the head and conditions of setting are different from those under which the wheels are afterward installed, information of especial value will be afforded by tests such as those just cited, in which the same wheels are first tried out at the standard station and again after permanent installation. It is only by such comparisons that we may get sufficient light upon the error involved in computing from a Holyoke test the proper speed and probable output of the same wheel under a different head.

4 In making such computations it seems ordinarily to be assumed that the various losses of head from shock, friction, leakage and residual velocity will vary in the same ratio in which the gross head varies, and that consequently, the turbine efficiency will remain constant for the same gate opening and same relative speed; while as a further consequence the discharge will vary as the square root of the head. So far as theory goes, it indicates that these laws will approximately hold, but it can hardly be supposed that they will hold rigidly.

5 Even through a standard fixed orifice the discharge seems not to vary strictly as the square root of the head, but is affected by a changing coefficient which must be found experimentally. How, then, can the theoretic law be expected to hold exactly in the case of flow through a revolving wheel with its appurtenances of casing, guides, gate and draft tube. Draft-tube losses themselves are but little known and must be uncertain disturbing influences in many cases.

6 How much the common method of adjusting to a different head the results of a Holyoke test may be in error is only to be learned by comparisons such as Professor Allen carries out. Even though the error be but small in percentage, on large installations it may be a matter of much importance.

Prof. George E. Russell.[1] One of the greatest stumbling blocks in the path of turbine development in this country has been the lack of systematic testing after installation. Errors in design have been made and perpetuated year after year, simply because purchaser and manufacturer have been satisfied to believe that turbines showing splendid results at Holyoke under a head of 18 ft. or less would give as creditable performances when used with heads five or ten times as great. That this was beyond the limits of reason we know now and should long since have known.

[1]Assistant Professor of Civil Engineering, Massachusetts Institute of Technology, Boston, Mass.

2 Under the low heads which were the first to be developed in this country, it was necessary to meet the demands for increased speed and power by decreasing the diameter and deepening the wheel axially. As the decrease in diameter prevented the free escape of water from the radial inward-flow wheel of Francis, it became necessary to change the shape of the buckets in order to turn the water in them to an axial direction. Thus the Francis wheel was gradually metamorphosed into the vortex type. This wheel has been developed to a high degree under low heads by experimental testing at Holyoke and elsewhere. Very little, if any, of this class of work has been done under high heads, and there are enough reliable data to show that the general type of wheel so far produced in this country is not as efficient as designs from abroad which are based on the radial flow type. As to whether the vortex type can be brought to perfection under these conditions or not there appears to be some difference of opinion, and no intelligent answer to the question can be given until many reliable high-head tests are available. If the answer is to be favorable to the American turbine, then the attainment of this high efficiency can be possible only by development through experimental high-head testing. The shape of the American runner passage is so intricate as to defy mathematical analysis of the water's action, and in this respect at least the European design has much in its favor.

3 The wide and general continuance of the work so ably and carefully started by Professor Allen should be encouraged and advocated by all engineers interested in the highest possible achievements in water power development in this country.

H. K. Barrows.[1] To improve the efficiency of turbines it is necessary to have an accurate determination of the quantity of water used by the wheel, as well as its power output. Even the standard weir, as it is usually installed under the conditions of a field test, is subject to errors of 2 or 3 per cent or more. Professor Allen showed a view of a large weir installed in a canal for such a purpose and it is evident that the expense of such construction would prevent its use in many cases. Then again, it is often undesirable to create such an obstruction to flow in a canal or tail race. Under such conditions resort must be had to some form of current meter to measure the discharge and the error in determination of flow may rise to 4 or 5 per cent. Ex-

[1]Associate Professor of Hydraulic Engineering, Massachusetts Institute of Technology; and of Barrows & Breed, Consulting Engineers, Boston.

cept in unusual cases the field determination of efficiency cannot be made as closely as at Holyoke, and the Holyoke tests will always be valuable as a standard of water-wheel testing. When compared with field tests such as are made by Professor Allen, valuable conclusions can be drawn.

2 Complete field tests, including discharge and efficiency as well as power output, are desirable, not only to bring about improvement in wheel settings and connections but also to insure suitable conditions of water approach and discharge.

3 With some forethought it would be possible in many cases to arrange suitable conditions for current-meter measurements at little or no extra expense, either in the canal or tail race, and in an important water power development this feature of discharge measurements should certainly be kept in mind by the designing engineer. The necessary platform or supports for operating a meter could be provided for at slight cost. A well-designed wheel pit, draft tube, and tail race should afford hydraulic conditions suitable for current-meter discharge measurements.

4 The prevailing idea on the part of wheel users has heretofore been to secure the desired power, oftentimes at a great sacrifice of efficiency, and the testing of wheels in place and at Holyoke is doing much to bring this fact home.

Henry D. Jackson.[1] Many of the wheel manufacturers have gone to extreme pains to put their wheels into splendid condition for testing at Holyoke and the wheels have shown correspondingly excellent results, but these conditions would not last long, so that in actual practice the wheels would doubtless show quite different results from those obtained at Holyoke. This has led to the discrediting of the Holyoke tests by a considerable number of purchasers as well as by engineers, especially abroad. To what extent this discredit is well founded I am not prepared to say, but an examination of some of the catalogues, data for which was furnished from the Holyoke flume, leads me to believe that there is reason to question some of the Holyoke tests, particularly when used as they are by some manufacturers. It has been found by actual trial that wheels tested at Holyoke and then shipped elsewhere, for tests, particularly abroad, have shown very much lower results than at Holyoke.

2 As a rule, the purchaser of the wheel desires to know its effi-

[1] Consulting Engineer, 88 Broad St., Boston, Mass.

ciency under all conditions of load at a rated speed. The Holyoke tests, however, as quoted in catalogues, allow the wheel to assume its own best speed under each condition of gate opening, so that the speed neither remains constant nor holds a constant relation to the head. The tests are, therefore, subject to correction, which most purchasers are unable to make. The figures in Table 1, data for which are claimed to have come from the Holyoke testing flume, are quoted from the catalogue of a certain manufacturer, and an examination of a number of Holyoke tests discloses these same conditions.

TABLE 1 TESTS ON THREE SIZES OF WHEELS

	Gate Opening	Speed	Efficiency	Head
A	Full	194.25	81.08	15.29
	7/8	187.75	84.78	16.56
	3/4	178.50	83.88	17.33
	5/8	176.40	80.09	17.54
B	Full	144.00	82.03	15.00
	7/8	138.12	84.55	15.04
	3/4	127.67	83.68	15.11
	5/8	131.50	80.25	15.88
C	Full	109.00	83.58	13.27
	7/8	101.00	85.01	13.79
	3/4	100.00	81.06	14.69

3 The tests start as a rule with full gate and at a rated discharge, and a number of runs are made with different loads and speed. Then the discharge is decreased and another series of runs made. If under full-gate opening the speed which corresponds to the rated discharge of the wheel is noted and attempts made to find under the different gate openings this same speed, it will as a rule be discovered that the speed decreases constantly with decreased gate. Rarely is the full-gate speed maintained or even quoted in the test results on the decreased gate openings.

4 Another reason for so much questioning of the Holyoke tests is the extremely high efficiencies which are sometimes quoted. For instance, a short time ago it was reported that a certain wheel showed approximately 94 per cent efficiency at the Holyoke flume. The theoretical efficiency of a water wheel would rarely exceed 97 per cent and theorists on water-wheel design claim the losses vary from 12 per cent upwards, so that such efficiencies seem to be very questionable, unless the theorists are mistaken in the value of the various losses.

The wheel manufacturers do not as a rule guarantee their wheels at over 80 per cent efficiency and this would seem sufficient reason to believe that they themselves do not place too much reliance on the results obtained at Holyoke. There are times, however, when wheel manufacturers will guarantee considerable increases over 80 per cent. But I am strongly inclined to believe, partly from experience, that they will balk when the purchaser asks that this guarantee be placed on paper, that the wheels be tested, and that a bonus and forfeiture clause be put into the contract. For these reasons, it seems to me decidedly advisable to test the wheels under conditions of installation, and the device used by Professor Allen appeals to me very strongly.

5 It is, however, open to some objections. Unless used with extreme care it would seem as though the results would be higher than the actual conditions of the installation should show. Suppose a generator be removed from the water-wheel shaft and a dynamometer be substituted. If the dynamometer be carefully balanced so that none of its weight is taken by the water-wheel bearings, is it certain that some of the weight of the water wheel is not removed from its bearings, thereby reducing the friction? In many cases the water wheel is fastened directly to a coupling on the generator shaft, so that the water-wheel bearing is also the bearing for the generator. At the same time, however, a large part of the friction on this bearing should properly be charged up against the water wheel, so that it is important in using this dynamometer to be sure that the bearing friction of the wheel is the same as it will be when the wheel is in actual service. This point being assured, the test, so far as the actual power delivered by the wheel is concerned, is a relatively simple matter. In case the water wheel is belted to lineshafting or any user of power, or in case it may be connected by gearing, the use of the dynamometer does not throw the same thrust on the bearings as exists where the wheel is actually doing its usual work; and as the power delivered by the wheel should take into account the losses in its bearings under conditions of actual service, it would seem to me as though the dynamometer test would show higher results than should reasonably be expected.

7 In making the tests certain errors exist outside of the dynamometer. These are in the measurement of the water and the measurement of the head acting on the wheel. The water in many cases may readily be measured by means of a weir and if the weir is properly proportioned the measurement may be quite accurate. It is seldom possible, however, to use a weir of standard dimensions and any change in the form will introduce errors of greater or less magnitude. The

head acting on the wheel will be affected by conditions of setting, methods of getting water to and from the wheel, the shape of the penstock and draft tube, and the location of other wheels near that under test. On very high heads there is also a possibility of considerable error in determining the actual head working on the wheel.

8 I am glad to know that Professor Allen believes the test made by the use of the electric generator as a basis of measurement of the power delivered by the wheel is perfectly satisfactory. The efficiency of an electric generator can readily be calculated under practically all conditions of load and there should be no trouble in the use of the necessary instruments for determining the output of the machine. The effects of temperature or magnetism can readily be overcome and the error in the instruments to a large extent eliminated by the use of duplicates and care in handling the instruments in transportation and in service. The question of absorbing the power generated is a very different matter, as frequently it is difficult to design the apparatus necessary to absorb very large amounts of power without very great fluctuations. The water rheostat, while valuable in service, is not always easily controlled; nor is it always easy to vary the load of a generator over sufficiently wide ranges and speeds to give all of the characteristics of the water wheel which may be desired. These characteristics, however, are of service only to the investigator and the designer of the wheel and are not strictly for the purpose of determining whether the wheel is or is not up to its guarantee.

9 One of the great advantages in the use of the generator as a method of testing is that it is a permanent part of the installation, available for tests at all times, thus enabling the owner to check up the efficiency of the wheel and the conditions of installation and to determine whether or not anything has arisen to reduce this efficiency, or whether changes in the plant have in any way affected it. This is sometimes an important consideration.

10 In conclusion I would like to ask if there are not chances for error in the calibration or measurement of the brake constants.

H. C. Daggett. At the present time there is probably no feature of a hydraulic plant about which there is so little definite data as in connection with draft tubes. One reason is that no testing flume exists today which is suitably arranged and designed for making tests of draft tubes of different sizes and shapes. When water wheels are tested in place certain results as to power and efficiency are obtained, but there is no means of knowing to what extent these results are due

to the design of the draft tube. For example, a pair of water wheels may be tested in place with a certain kind of draft tube and may give good results, while another pair tested with another type of draft tube may give poor results, but we do not know that the difference in efficiency was entirely due to the difference in the design of the draft tube. It may have been due partly to the draft tube, to the difference in the actual efficiency of the water-wheel runners, to the way in which the water enters the wheel case or flume, to the difference in the design of quarter-turn or center case, to the number and design of bearings, or to other details. In other words, the actual tests in place are so comparatively few, and the conditions apart from the design of draft tube are so seldom alike, that it is safe to say that we seldom or never test two units of water wheels where all the conditions except the draft tube are the same.

2 Therefore, each designer of water wheels uses his own ideas as to the proper form of draft tube to be used in any particular installation. He is influenced, of course, by the conditions to be met and by his own personal experience. He may design a draft tube with a view to saving rock excavation or, in case of a renewal of water wheels, to avoid changing the old wheel pit. In the case of horizontal water wheels, he is often influenced by the necessity or desirability of placing the elevation of the wheel shaft above tail water in time of freshet. Oftentimes, however, he has the choice of several different designs of draft tube, and it is difficult for him to know just which particular design would give the most efficient result. Some writers on hydraulic subjects have given tables showing the length of draft tube which may be used with different diameters of tubes. These tables, however, are arbitrary and are simply one individual's idea in regard to that particular point. The writer believes it is true that, everything else being equal, a vertical, conical draft tube will give greater efficiency than one built to any curve or set at any angle with the vertical. On the other hand, a draft tube that leaves the water wheel vertically and discharges horizontally in the direction of discharge of the tail race eliminates loss of head in the wheel pit to a large extent, and in many cases the gain in head would no doubt offset the greater efficiency that might be obtained with the vertical tube. Lack of information on this point, however, makes it impossible for us to say in any given case which would be the more efficient design and how much more efficient. Again, by constructing a draft tube at an angle from the vertical oftentimes a certain amount of excavation can be avoided but it is impossible to say whether the loss in efficiency by so doing is compensated for by the saving in the cost of excavation.

3 Some engineers have maintained that a properly designed draft tube should have a certain fixed angle of flare, regardless of the length of tube, velocity in the tube, or other conditions. The writer has had access to certain experiments on small tubes, however, which indicate that the best angle of the tube depends on the length of the tube, the velocity of the water in the tube, and the head under which the water wheel is operating.

4 It would certainly be very desirable if a testing flume were available where careful experiments could be made of the results obtained with different designs of draft tubes, where at the same time all other conditions could remain the same, showing that the difference in results was entirely due to the difference in draft tube design. Such tests would be invaluable and the writer hopes that arrangements may be made in the near future whereby such a testing flume may become available for the use of engineers, users and builders of water wheels.

SYMPOSIUM ON ELECTRIC DRIVING IN MACHINE SHOPS

The paper by A. L. DeLeeuw on The Economy of the Electric Drive in the Machine Shop, published in The Journal for November 1909, resulted in the holding of a joint meeting of the Society with the American Institute of Electrical Engineers in the Engineers Building on April 12, 1910, on the general subject of Electric Driving in Machine Shops. In addition to Mr. DeLeeuw's paper, three others were given, one by Charles Robbins on Electric Motor Applications, another by John Riddell on Mechanical Features of Electrical Driving, and a third, contributed by the American Institute of Electrical Engineers, by Charles Fair on Motor Application to Machine Tools. The same papers were discussed at a joint meeting of this Society with the St. Louis Section of the American Institute of Electrical Engineers and the Engineers Club of St. Louis on April 9. Brief abstracts of the papers and the discussion on them follow.

THE ECONOMY OF THE ELECTRIC DRIVE IN THE MACHINE SHOP

By A. L. DeLeeuw, Published in The Journal for November 1909

ABSTRACT OF PAPER

This paper calls attention to a number of factors affecting the economy of electric drives in the machine shop, but makes no attempt to give figures or formulae by which the economy could be computed. On the other hand, it attempts to show why such figures or generalizations cannot be of any value at the present time. This is due partly to the lack of reliable data and partly to the fact that much of the benefit of the electric drive comes in a form which makes it unfitted to quantitative analysis. The paper further shows that each problem of installation or conversion must be treated by itself and proceeds to show which elements are mainly to be considered.

MOTOR APPLICATION TO MACHINE TOOLS

By Charles Fair, Published in the Proceedings of the American Institute of Electrical Engineers for May 1910

ABSTRACT OF PAPER

This paper discusses the advantages of the individual electric drive for machine tools, with special reference to tools which are already in service

with belt drive. In such cases it is necessary to consider in choosing a motor, the nature of the work, the speed changes required, the number of tools thus to be equipped, and the condition of the tools. Even where a motor is applied to a tool designed for belt drive, the new drive should be simple in construction, satisfactory in operation, and sightly in appearance. Numerous methods of attaching motors to old tools are shown and described.

The choice of control, whether it be with old or new tools, is fully as important as the choice of the motor and it is necessary to consider the accessibility of the controller to the operator, the method of attaching it to the tools, and its relative position to other tools. Accessibility in case of accident is an important consideration and the starting compensator should be placed where the motor or some of the moving parts can be seen by the operator. Wherever possible, both controller and motor should be attached directly to the tool. In the case of portable tools this is an absolute necessity. The effect of convenient control upon the output of the tool is emphasized and various types of controllers and methods of application are shown and described.

A table is attached which is designed to aid in a general way in the choice of motors, and numerous methods used to maintain standard motor shafts are illustrated.

ELECTRIC MOTOR APPLICATIONS

By Charles Robbins, Published in The Journal for April 1910

ABSTRACT OF PAPER

In this paper are outlined the uses of a graphic recording current-meter in connection with individual machine tool drives, in showing actual working time, in detecting delays from any cause, in checking the rate of removing metal, and in establishing and maintaining the rate for maximum economy.

The relative merits of the lineshaft and individual motor drives are discussed and a table given showing graphically the superiority of the latter.

The five appendices supplement the paper and pertain to the following subjects:

a The characteristics of various machine tools as shown by diagrams from recording meters.

b Data on the power required to remove metal under the conditions set forth in the appendix, together with convenient charts for determining the various factors mentioned.

c A summary of the average horsepower equipment for different types of tools and the approximate speeds of the motors which are normally selected for this work.

d Calculations to determine whether it is more economical to equip an old machine with a motor or to purchase a complete new motor-driven equipment.

e Over-head charges and machine hour rates.

MECHANICAL FEATURES OF ELECTRIC DRIVING IN MACHINE SHOPS

By John Riddell, Published in The Journal for April 1910

ABSTRACT OF PAPER

This paper is principally devoted to the various mechanical means employed in attaching individual motors to machine tools, with particular reference to the practice of the General Electric Company. Each of the common machine tools is treated separately and illustrations are given of the mechanical devices employed in attaching the motors. Several auxiliary devices are described, such as muslin pinions to prevent noise in gear trains, and rubber buffers between the gear and the driving spindle to prevent chattering on finished cuts.

DISCUSSION AT ST. LOUIS

M. L. Holman. There is no business of any kind where there is no ready-to-serve charge. The difficulty arises in this country from our adoption of the English system of estimating and accounting before the people were ready for it. In England the charge is called the standing-by charge. The same thing appeared in this country as a ready-to-serve charge and met with opposition everywhere. The charge is a just one, but is not generally understood. All concerns that do not go to the wall have that item in their charges somewhere.

2 I wish to call attention to the fact that as our machinery develops we go from the pioneer stage into a higher degree of civilization and our machine shops as well as our engineers have to stop making things and manufacture them. The young men of today are the men who must operate the country that has grown to an extent where the operation begins to be visible. The building of a pioneer country is an entirely different proposition. Germany has come to a point where it is almost entirely a question of operation. If they do not manufacture more cheaply than other people they will starve to death and some of the other European countries are in nearly the same position. Of course it will be years before this country must face such conditions, but we are just entering that stage of our engineering progress where we must begin to manufacture things and stop making them.

Prof. W. F. M. Goss. A few years ago it was commonly believed that the electric motor could only be used under certain favorable

conditions. If there are any who today hold such an opinion, they should visit the great steel works at Gary, Ind., where not only machines but compressors and roll trains are electrically driven, to be convinced that there is nothing in machine driving that can not be done by the electric motor.

2 A modern machine shop, whether for repairs or manufacture, presents an equipment of specialized machines. The capitalization which underlies the operation of the shop has been extended enormously in these later days, and the added cost of a motor to drive an individual machine is now more easily met than formerly. If the layout of the shop is properly balanced and if there is business sufficient to keep the machines going, an individual motor for each machine will increase the output and improve the efficiency of the shop.

3 I do not believe that there are many cases where it will pay to fit motors to old machines. There may be individual cases where this may profitably be done, but the new motor and the old machine will always be less efficient than a complete new outfit. If a point is reached in the development of a shop when electrification is in order, it will generally pay to provide new machines which will be up to the standard of the motor.

4 I am convinced that the machine tool of the future is to be an individual motor-driven machine, a machine in which we will not see pulleys, belts, or gears. Such a machine will not only be powerful, ready for instant service and easy to maintain, but it may be taken from its station if desired and moved to its work. It will be an instrument which, because of these facts, can be used in the development of a much larger output than will be possible by machines of the ordinary characteristics.

E. R. Fish.[1] There are probably few manufacturing plants designed at present which do not provide in a greater or less degree for electric transmission of power. In many instances provision is made for a generating plant, but sometimes it is more economical to purchase current from a central station. My own experience has been in connection with a shop for the manufacture of boilers. In plants of this kind several methods of power transmission are required, but a great many of the tools can best be driven by motors. In fact the use of motors permits the only rational layout of a shop of this sort or economical production. Any other form of motive power can be

[1] Secretary, Heine Safety Boiler Co., St. Louis, Mo.

used only at great inconvenience, with poor economy, and with large maintenance charges. With motor drives the machines can be located exactly where they are wanted and where the successive operations will progress without unnecessary handling or delay. We use the 220-volt, 3-phase, 60-cycle current and have found it e tirely satisfactory. It drives plate-working tools of all sorts through individual motors, drives a small machine shop through a lineshaft, and operates a 25-ton traveling crane. In our case it was quite impracticable to use power from a public-service station because our processes required a power house of our own. We did want an emergency connection from the outside in order to provide against possible failures of our own generator but the ready-to-serve charge was quite prohibitive. A large portion of our work is done by hydraulic and pneumatic tools, so that even though the generator should fail, the works would not be entirely shut down. It is therefore unnecessary that this charge be incurred. It is undoubtedly true that in many instances the protection against break-downs which would completely close the plant would justify the cost of such an outside connection.

A. H. Timmerman.[1] The choice of direct or alternating current for machine shop drives depends largely upon whether there is a possibility of throwing over to a power company's circuit. If the ready-to-serve charge is not too great, the alternating-current distribution is by far the best, because in case of failure of supply the alternating current of the power company can be relied upon.

2 In the case of an individual installation in which the amount of power required is large and there is no public service corporation to rely upon, the question of direct or alternating current is largely a question of the area covered by the plant. Alternating current is satisfactory for both small or large plants but direct current is hardly suitable for a plant extending over a considerable area because of the large drop in voltage due to the long lines required.

3 Six or eight years ago a great deal was heard about adjustable speed motors for all forms of machine tool drive, but machine tool builders have found it necessary to build their tools so as to get the necessary changes in speed mechanically.

4 I was rather surprised that emphasis was placed on the squirrel-cage polyphase motor. There is an increasing demand on the part of the power companies for the wound-rotor type. The squirrel-cage

[1] Superintendent, Wagner Electric Manufacturing Co., St. Louis, Mo.

draws a very heavy current at starting in comparison with that used by the wound-rotor type. With the latter type full load torque is obtained with full load current, or double torque with double current. The squirrel-cage type requires for full load torque from two to four times full-laid current, depending upon the design of the motor.

5 In this connection it is also of interest to note that the single-phase alternating-current motor can be used just as well as the poly-phase motor for tool drive. In fact in many installations it is much better because a single-phase motor, starting on the repulsion principle, has an exceedingly high torque and draws very much less current from the line for a given torque, than is drawn by any other type of motor.

6 The amount of power drawn for any tool varies from one-tenth full load to a load and a half, and a motor must be put on an individual tool which will take care of the largest load that the tool is liable to have. On the other hand, if five or ten tools are grouped together, a motor that is perhaps a quarter of the sum of the individual horse-power capacities required on the different tools may be installed. This is shown by the fact that even where a group drive is used, the actual power drawn from the generator is very often not in excess of 40 to 60 per cent of the total horsepower connected to the generator.

7 In the installation of alternating-current motors care should be taken that motors not too large for the work are chosen. The alternating-current motor has a very much heavier overload capacity than the direct-current type, and since the power factor at fractional loads is rather low, it is better to have alternating-current motors overloaded than underloaded.

P. A. Morse.[1] If it is necessary to use alternating current from the source of power it is very frequently advisable to put in motor-generators to take care of machine tools or of hoist motors in such a way that a much better power factor is obtained, thereby decreasing the watt load and increasing the capacity of the generating units. The Grand Trunk shops have some large motor-driven compressors to which are coupled synchronous motors. At a plant in St. Louis in which the power factor was very low, the slip-ring type of alternating-current motors was used for certain work. When these were changed recently to direct-current, it increased the power factor and the capacity of the generating plant.

[1] Engineer, Western Electric Co., St. Louis, Mo.

2 While alternating-current motors, both single-phase and polyphase, have in recent years been adopted very widely as sources of power in the machine shop, the fact still remains that with a class of work which calls for mechanically different sizes of material to be passed through and where the processes on a given machine tool are not the same from day to day, it will be almost imperative to use the direct-current motor.

3 Recent practice in direct-current motors is to furnish them with inter-poles to improve the commutation and the advantage claimed for the alternating-current motor, that it gives less trouble, should not be as much of a factor hereafter.

4 The alternating-current motor, of course, has practically only the bearings to look after, but the narrow air-gap, which is necessary in order to correct certain other things which make the motor undesirable, must be balanced against commutator trouble. Within the last few years considerable work has been done in battering the commutation of motors. This fact has not been generally recognized but will have its bearing on future installations.

H. H. Humphrey.[1] In connection with stand-by service from a public utility company, it is often an advantage to be able to start part of the plant before the power plant is ready. I know of one case where the entire plant ran for about three months on central station power. This service has been abandoned this year because it was found that the isolated plant is much more reliable than the central station service in this particular case.

2 As an industrial plant grows in size, it generally puts in reserve capacity, which is kept ready to serve, while on the other hand the central station companies are generally overloaded. If they are not this year, they will be next, for the reason that they connect more customers than their total capacity.

O. Stephensen.[2] There are one or two points on which I would like to take issue with Mr. Morse regarding the relative merits of direct and alternating-current motors. There are many cases in which a constant-speed motor can be used, especially for quantity manufacture. Only where the work changes from one job to the next or from moment to moment is an adjustable speed motor required.

[1] Consulting Electrical Engineer, Chemical Building, St. Louis, Mo.

[2] Electrical Engineer, Wagner Electric Manufacturing Co., St. Louis, Mo.

2 I also take issue with the objection made to the alternating-current motor because of the small air gap. Even with an air gap of only a few thousandths of an inch, proper care, which means nothing more than the right kind of oil in the bearings and the right amount at the right time, will prevent the rotors wearing on the stators, if the bearings are designed liberally enough. The latter point is therefore a very important one to the purchaser of an alternating-current motor.

William H. Bryan. The State Railway Commission of Wisconsin has been doing some admirable educational work towards a better understanding of the ready-to-serve charge. They are fixing rates for all the utilities in that state, and are doing it very thoroughly and well.

2 I do not like Mr. Robbin's method of charging depreciation as outlined in Appendix No. 5 of his paper. This method, which he says is in general use in appraising shop tools, is to charge off a certain amount each year. He gives it as 10 per cent, which I find a very common figure. The next year they charge off 10 per cent of what is left, the next year 10 per cent of what is left of that, and so on, so that tool may be thirty or forty years old and still have book value.

3 The more modern way of handling depreciation is the sinking-fund scheme, by which the probable life of the tool is first estimated, by a study of its service, and then an amount is set aside each year, which will, with interest compounded annually, at the end of the assumed period of life, have replaced the full value of the tool. To ascertain the value at any intermediate date the amount of the accumulation in that fund is deducted from the cost of duplicating the tool.

Prof. H. Wade Hibbard. I recently visited the St. George Street plant of the American Car and Foundry Company in St. Louis where electric driving is applied to a wide range of work. That plant, engaged in the manufacture of steel cars, is very large and compact. Since it is engaged in the manufacture of a large number of parts that can be produced on a factory basis, they have adopted alternating-current motors. The large machines are individually driven, and the small machines are group-driven. One is impressed in such a plant with the change that has come about in machine shop practice in recent years.

DISCUSSION AT NEW YORK

Charles Fair.[1] It is disappointing that so many of the tool builders fail to take advantage of the increased production which would result from proper attention to the convenience of control. There are many cases where the tools are so arranged that the control might easily be damaged by trucking, etc., or sometimes the control is placed 40 or 50 feet away from the motor, necessitating considerable useless wiring. Others often place the operating handle in such a position as to make it a back-breaking job for the operator.

2 For electrical reasons it is of course not practical to build motors with a ratio so great as 15 to 1, nor can I agree with Mr. Eberhardt that such a large ratio would be desirable or necessary for a large majority of the work. The question of standardization of speeds and principal dimensions is not impossible, but that the tool builders would be satisfied with such a standard is not at all probable, inasmuch as there is a decided difference of opinion among them both as to speeds and shapes of motors.

3 An unfortunate circumstance which often surrounds discussions relating to electrical apparatus for tools is a lack of knowledge on the part of either side of the limitations and requirements of the other. Much of the trouble which tool builders are experiencing today could be eliminated were they to discuss their difficulties more freely with men who are conversant with both sides of the subject.

Henry Hess. I cannot agree that the direct-connected motor drive is always and everywhere the only correct thing; nor do I reject it absolutely and utterly for every shop, place and tool. Both attitudes are too radical and sweeping; truth will be found as usual between the extremes.

2 The direct-connected motor drive is distinctly preferable where any advantage in quantity of output results from its use, or where a machine is to be portable, or so located that it can be reached only by long or awkward lineshaft and belt drives. Under every other condition the individual motor drive is more expensive in initial installation and upkeep, and more complicated to maintain in the average shop.

3 The absence of overhead and vertical belting is an advantage that appeals to the extremist. The amount of light obstructed is

[1] General Elec. Co. Schenectady, N. Y.

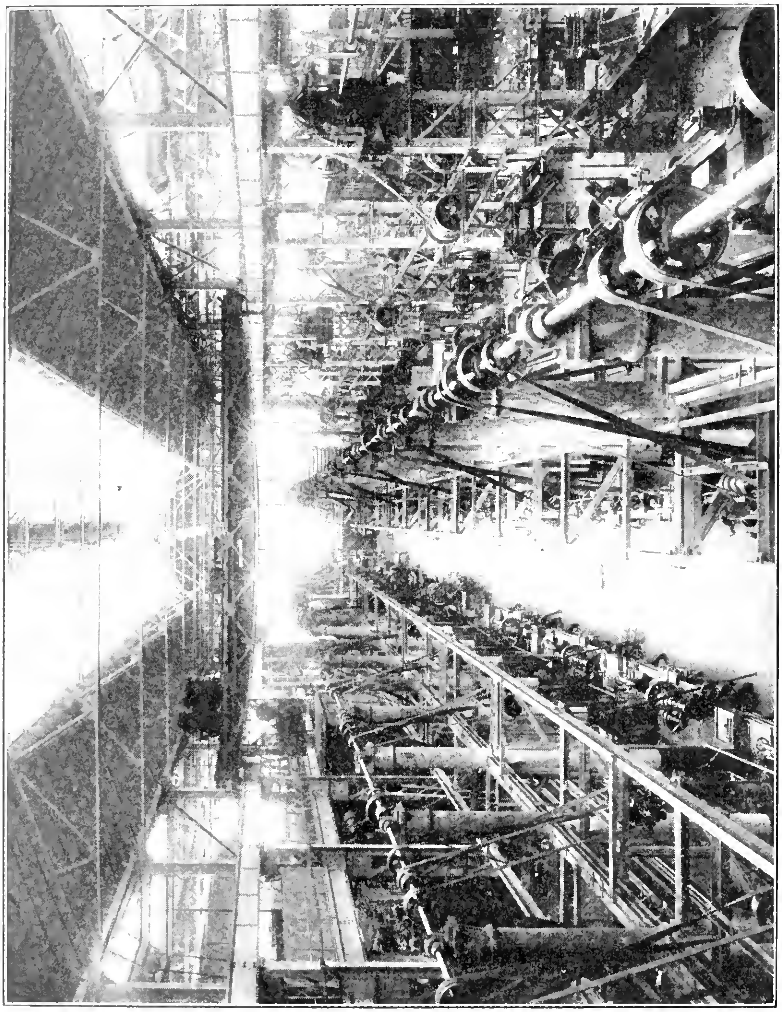

Fig 1 Belt-Driven Machine Shop from Above

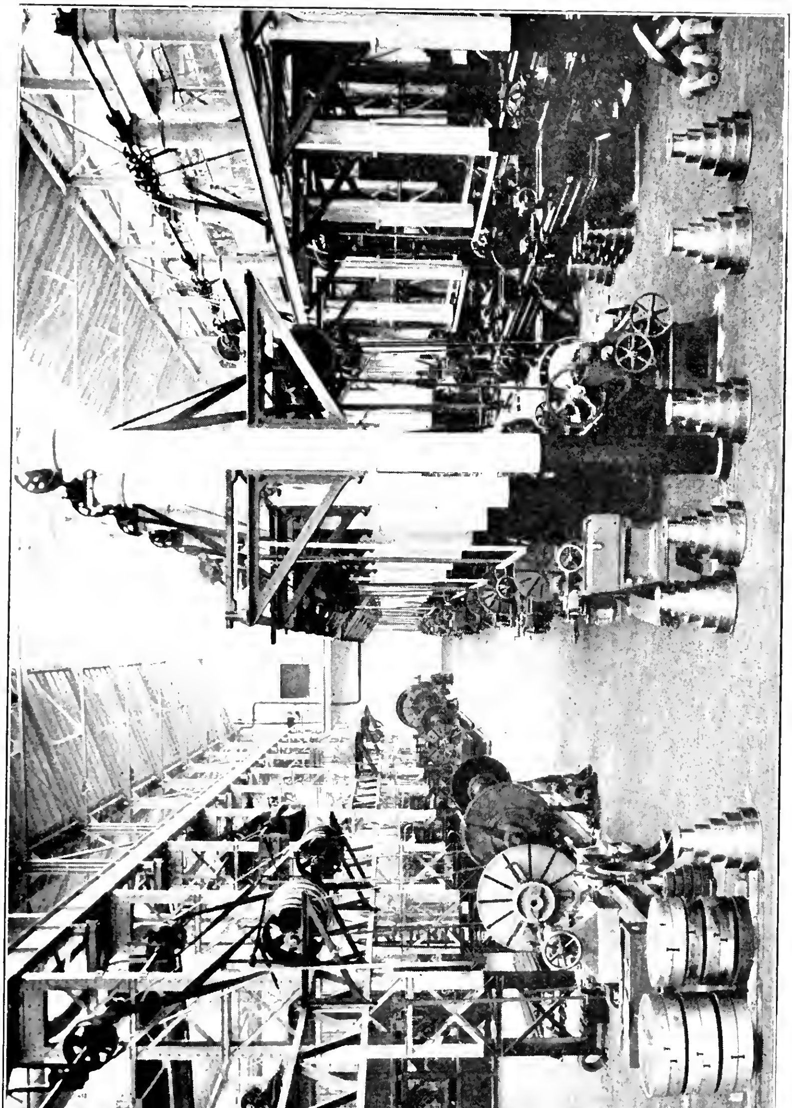

Fig. 2 Same as Fig. 1 from Below

inappreciable, be the shop of the modern well-lighted type or one or the older dark interiors. The horrible example which Mr. Riddell shows (Fig. 1) is most carefully selected; but is not necessarily representative. In contrast note Figs. 1 and 2 herewith. Here are six parallel rows of lathes in a shop bay 50 ft. in width. The two side rows are driven from lineshafts carried on the crane columns. The four central rows are driven from two lineshafts that are mounted on cast-iron columns standing free of the building. Cross-arms from these support longitudinal channel beams to which the countershaft hangers are attached. The lineshafts are driven by alternating-current motors back-geared to the shafts. Note also the utilization of the crane-track girders for carrying the lineshaft that drives tools close to the crane columns. These lineshafts are also direct motor driven. There is no interference with the overhead traveling crane. Not the most rabid advocate of light has ever been able to criticise this installation for lack of it. Nor is there any noticeable interference with lighting when there is an overhead ceiling as in Fig. 3. Here again the lineshaft is driven by a motor attached to the ceiling.

4 Even eliminating all of the many establishments that could not fairly be classed as progressive, provided the test of progressiveness is not based on the direct-connected idea, an examination of the machine shops in a given city will fail to show the prevalence of the direct-connected individual drive, whether the comparison be made on the basis of number of shops, of machines, or of power transmitted. The conditions found in one city will be found true of others and of the country districts as well. The lineshaft and belting manufacturers are not yet losing sleep or going into the hands of receivers.

5 In the average machine shop, increase of capacity is, as Mr. Dunn quite correctly points out, of prime importance. Whenever increase in capacity is directly attributable to the individual motor drive, that should be installed; but in each case it should be carefully considered whether the same increase in capacity cannot be secured without it. Then the relative cost of initial equipment and maintenance should be the deciding factor.

6 That shop manager not interested in what his operation costs is likely soon to receive emphatic reminder that his lack of interest is not shared by those whose dividends are affected. Every possible saving should be taken advantage of every element of cost should be reduced if possible.

7 As producing engineers, we are all necessarily interested in advocating the particular thing we produce or help to produce. So

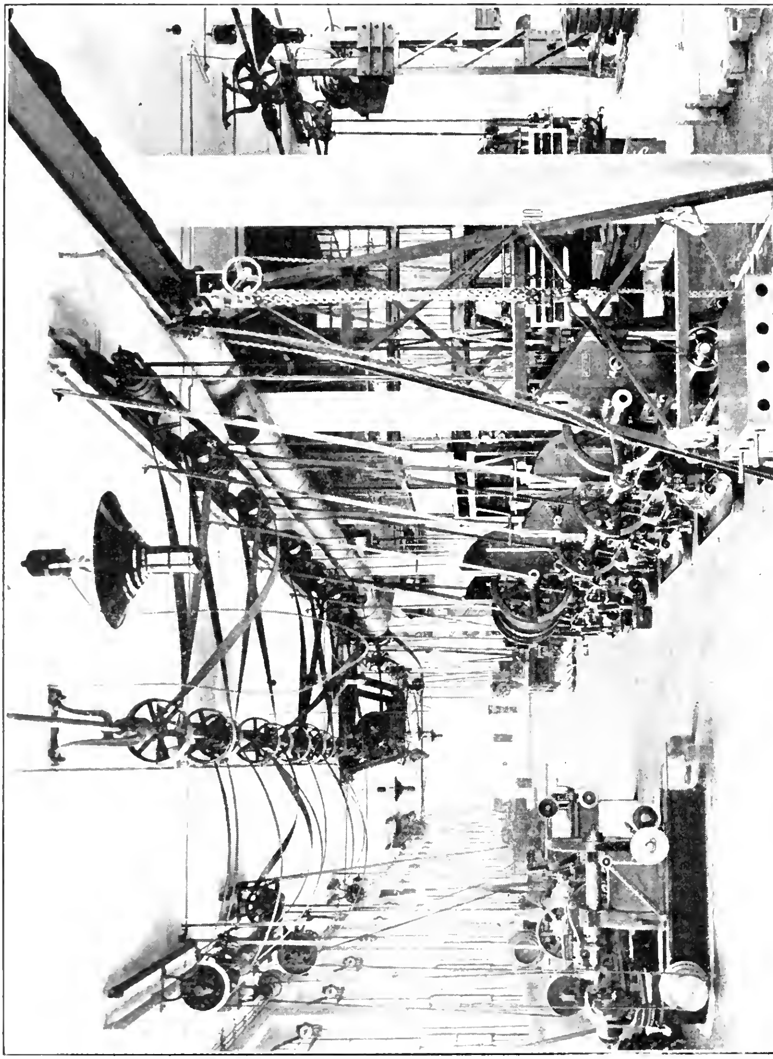

Fig. 3 Belt-Driven Machine Shop with Ceiling

far as my advocacy of the ball bearing is concerned that does not predispose me toward the ball-bearing lineshaft, for the simple reason that the ball bearing is quite as widely employed on electric motors as on lineshafts.

8 Can the most thorough-paced advocate of the electric motor claim for it that it delivers more power than may be transmitted through a belt? Should one be found possessed of sufficient temerity, then what explanation has he to offer for that species of direct-connected motor drive in which a belt is interposed between the motor and the machine? Many such are to be found in the shops of the best-equipped motor manufacturers, who, believing in the most thorough way in adopting what they advocate for others, equip throughout with motors to the exclusion of all lineshafts. Certainly these manufacturers and their shop managers do not go to the length of sacrificing capacity merely to be consistent. But they get that result in many cases through belts, and even through belts plus the despised countershaft, with the motor thus twice removed from the direct connection (see Figs. 5 and 9 of Mr. Riddell's paper).

9 Moreover, with belt drive the machine-tool manufacturer can build his machines in large lots without having to individualize for the almost endless diversity in electric motors. Attention has been called to the difficulties of reconciling the diametrically opposed needs of the electric motor and the machine tool. All of these difficulties are solved by the gear box already in more or less general use by many machine tool builders. It may be driven by either a direct-current or an alternating-current motor or by a belt from a lineshaft or countershaft. All it asks is that the motor or belt be of sufficient size to satisfy its hunger for power.

10 A motor is many times more costly than a belt, wastes far more power in journal friction and windage alone than the belt uses up, and in addition has great electrical losses. Mr. Robbins, in advocating the motor, admits a motor waste of one horse-power to every three usefully delivered. What belted drive can be accused of similar wastefulness and inefficiency? Remember also that the belt drive does not vary in speed even by a few per cent. Can that be said of the electric motor? Even its advocates have admitted the contrary.

11 Great credit is due the manufacturers of electric machinery for having given an impetus to the art of economical machine production. They have not only stimulated the advance through constant demand on the machine tool builder but they have also shown him the way by example. Naturally they have made the widest possible

use of that means of power transmission which constitutes one of their staples of manufacture. That has focussed attention on the methods they advocate. Other methods no less meritorious, or even superior, with no such strenuous and interested advocates have not been similarly brought to public attention, and possibly have not felt the need.

12 The essential matter which the man responsible for final costs must weigh is not that of direct-connected individual motor drive, or of any other drive, but the one of final total cost as influenced by all factors. So far as the transmission and application of power is concerned, it is a matter of largest output at least cost. It must be by motor if that gives more output than can be realized by shaft and belt. It must be by shaft and belt if that can give as great an output as the motor. The decision must so fall, simply because of lower first cost and lower upkeep cost.

13 Stress has been laid in the papers on the economical features of the direct electric motor drive. Whenever such application results in increased output, due to qualities inherent in the electric motor, then the direct motor drive is in order. Whenever the direct motor application does not inherently reduce operating time, then investigation is in order to determine whether the lineshaft drive is not more economical and the direct motor application a compliance with a fad to be dearly paid for.

14 The impression given by the papers is one of the all-round superiority of the direct-connected motor. It is only in the following instances, however, that the individual motor drive over-balances the economic features of the lineshaft:

- *a* Where machine portability is important.
- *b* Where relative under-equipment with large machines makes their overtime operation necessary, while the balance of the plant is idle.
- *c* Where occasional machines can be reached only by long lines of shafts or are inconvenient to drive from the lineshaft.
- *d* Where the direct motor application results in increased productive output not otherwise obtainable.

15 In every other case the lineshaft has the advantages of lower first cost, lower cost of maintenance, smaller depreciation, less power waste and less grand total of annual costs.

16 Moreover, the differences are very decided. This is true even

when the lineshafts are mounted on plain bearings with their large friction wastes. It is still more true when these friction losses are reduced by mounting the lineshafts on ball bearings of a durable type. The difference is still further increased in favor of the lineshaft when it is run at the high speed that ball bearings make feasible. High speed decreases weight of shafting, weight of pulleys, weight of belts, and with these the journal loads and losses, as well as the first cost of every element in the system.

17 Realizing that definite figures rather than general statements are wanted, I have made direct quantitative comparisons, using as a base an existing, well-arranged plant of direct motor-driven machine tools. For this purpose our former president, James M. Dodge, placed the data and experience of the Link Belt Company's works at my disposal.

18 Fifteen representative machine tools cost for motors $4,920; for power annually at $0.03 per kw-hr. $2,930; for depreciation at 10 per cent and maintenance at 5 per cent $492 and $246 respectively. The total annual cost is $3,868.

19 A line shaft installation at 200 r.p.m. on plain bearings would cost only $520 initially and take $170 less annually for power, with a total annual cost of only $2838, or $830.00 less.

20 The same lineshaft, but carried in ball bearings would cost only $790 initially, save $330 in power annually and involve a total annual cost of only $2718, or $950 less.

21 Increasing the lineshaft speed to 600 r.p.m. and carrying this in ball bearings gives the most economical arrangement at an initial cost of only $460, an annual power charge reduced by $750 and a total annual cost of but $2249, or $1419 less.

22 Such a high-speed ball-bearing lineshaft system costs less than one-tenth as much to purchase as a direct-connected individual motor system, while involving less than two-thirds the latter's annual charges. Even this can be bettered materially by the employment of ball bearings in the countershaft and loose pulleys.

23 The data on which the foregoing is derived are given in detail in the appendix herewith, based on the tabulation in Table 1 of direct-connected machine tools in the shops of the Link Belt Company's plant, at Philadelphia.

APPENDIX TO DISCUSSION BY HENRY HESS

TABLE 1 DIRECT-CONNECTED MACHINE DATA

Motor No.	Motor Rating Horse-Power	Load Factor Per Cent	Motor Cost Dollars	Machine
43	25	14.4	583	120 in. Vertical boring mill
42	25	12.0	588	84 in. Vertical boring mill
76	9	16.6	268	37 in. Vertical boring mill
99	9	16.6	268	30 in. Vertical boring mill
100	9	15.6	250	Keyseater
61	3	20.0	159	Drill press
60	8	27.5	303	Keyseater
72	8	21.3	237	Keyseater
46	18	20.0	477	20 in. × 49 ft. lathe
44	12	8.3	440	30 in. × 27 ft. lathe
62	3	16.7	159	Cut-off lathe
104	12	14.2	440	Milling machine
39	9	36.5	263	Planer
59	8	18.8	237	Side planer
66	9	15.5	250	Screw cutter
Total	167	17.0	$4923	

24 As the total load factor in Table 1 is 17 per cent of the total motor rating, the total useful power delivered is $167 \times 0.17 = 28.4$ h.p.

25 In Par. 24 of his paper Mr. Robbins allows for the low load factor of direct-connected motors by assuming an average motor efficiency of 75 per cent. But this is not the whole story. Some prime mover, as a steam engine, must first drive an electric generator and the current must then be conveyed to the motor by wires. The generator efficiency will average 92 per cent and the line transmission 95 per cent. This makes a combined average efficiency for the generator, line and motor of $0.92 \times 0.95 \times 0.75 = 0.65$.

26 Using this value gives $\frac{28.4}{0.65} = 43.6$ h.p. as the average total power consumption.

27 The cost varies with local conditions, but will rarely be less than 3 cents per kilowatt hour, making the power cost for a year of 300 days at 10 hours $= 0.03 \times 43.6 \times 0.746 \times 3000 = \$2930$.

REFERENCES TO TABLE 2

28 The lineshaft and countershaft journal losses in Table 2 are based on a ratio of 1.94 to 1, in accord with Flather's findings of average machine shop conditions as quoted in Kent's pocket Book, 4th edition, p. 965.

REFERENCES TO TABLE 3

29 The loss of 13.2 h.p. on plain bearings in Table 2 is incurred by the lineshaft journals and the countershafts; it is reasonably accurate to apportion

TABLE 2 LINESHAFT DATA AT 200 R.P.M. WITH PLAIN RING-OILING BEARINGS

Shaft diameter $2\frac{15}{16}$ in. safe for 100 h.p. usual catalog rating	COST
Shaft length 100 ft.	$65 20
Main drive belt 14 in. by 30 ft.	90 62
Main pulley 56 in.	26 77
12 hangers, 26 in. drop with ring oiling bearings	81 60
15 double pulleys on lineshaft	37 25
15 sets of belts to drive countershafts	217 71
Total	519 15
Useful power delivered to the machines, as with the motors	28.4 h. p.
Lineshaft and countershaft journal losses	13.2 h. p.
Total	41.6 h. p
Total annual payment for power at $0.03 per kw-hr. and 3000 hours	
$= 0.03 \times 41.6 \times 0.746 \times 3000 =$	$2760 00

TABLE 3 LINESHAFT DATA AT 200 R.P.M. WITH BALL BEARINGS; OTHERWISE AS IN TABLE 2

Shaft	$65 20
Main Belt	90 62
Main pulley	26 77
2 D Hangers, with medium weight ball bearings next to main pulleys	80 34
10 C Hangers, with light weight ball bearings	269 90
15 pulleys on lineshaft	37.25
15 sets of belts to drive countershafts	217 71
	$787.79
Useful power delivered to the machines, as with the motors	28.4 h. p.
Lineshaft and countershaft journal losses	10.9 h. p.
Total	39 3 h. p.
Total annual payment for power at $0.03 per kw-hr. and 3000 hours	
$= 0.03 \times 39.3 \times 0.746 \times 3000 =$	$2600.00

TABLE 4 LINESHAFT DATA AT 600 R.P.M. WITH BALL BEARINGS

Shaft diameter $2\frac{15}{16}$ in. safe for 96 h.p. usual catalog rating.	
Shaft length 100 ft.	$ 48.00
Main drive belt 10 in. by 30 ft.	64.80
Main pulley 36 in.	10.19
2 B hangers 18 in. drop with medium weight ball bearings next to main pulley	34 68
10 B hangers 18 in. drop with light weight ball bearings	150.00
15 double pulleys on lineshaft	19.41
15 sets of belts to drive countershafts	129.52
Total	$456.60
Useful power delivered to the machines as with the motors	28.4 h.p.
Lineshaft and countershaft losses	4.1 h.p.
Total	32.5 h. p.
Total annual payment for power at $0.03 per kw.-hr. and 3000 hours	
$= 0.03 \times 32.5 \times 0.746 \times 3000 =$	$2180.00

this equally between the two. Ball bearings will save, under average conditions if other conditions remained unchanged, about 35 per cent of the lineshaft journal loss. In this case, therefore, taking the 13.2 h.p. from Table 2, 13.2 × 0.35 = 2.3 h. p. This leaves a loss of 13.2 − 2.3 = 10.9 h.p., as given in Table 3.

30 The loss could be reduced by another 2.3 h.p. by mounting loose pulleys and countershafts on ball bearings; but as these parts are generally furnished with the machine it is relatively difficult to secure them so mounted. It must be remembered that it is the user and not the builder of the machine who secures the benefits of the ball bearing mounting and it behooves the user to specify accordingly and to insist on compliance.

REFERENCES TO TABLE 4

31 Referring to the useful power delivered to the machines, the total line-shaft load is now only

$$\frac{1\tfrac{15}{16} \times 7110 \times 600}{12 \times 33{,}000} \times 0.0015 = 1 \text{ h.p.}$$

owing to the reduction in weight of the shaft, pulleys and belts and also the reduction in pull of narrower high-speed belts to 7110 lb.

32 The countershaft total load is 5000 lb., speed 400, but the friction is high at about 0.08 as conditions are not as good for the plain journals of the countershafts. This gives a loss of

$$\frac{2\tfrac{7}{16} \times 5000 \times 400 \times 0.08}{12 \times 33{,}000} = 3.1 \text{ h.p.}$$

33 Total loss = 3.1 + 1 = 4.1, as in Table 4.

L. R. Pomeroy. In Par. 3 of his paper, Mr. Robbins states that the alternating-current motor is essentially a constant speed machine. The variable-speed alternating-current motor, possessing series characteristics, is not adapted to general machine tool driving, but it can be used to more or less advantage to perform operations to which a series motor is adapted, such as driving bending rolls, cranes, etc. In a number of tools it is advantageous to vary the speed, to stop, start and reverse quickly in order to facilitate lining up the work, to take a trial cut, to adjust counterbore, etc. After such adjustment the open or synchronous speed can be used for cutting and the tool then becomes, through its working cycle, essentially a constant-speed machine. The additional speed changes, as outlined, are valuable as time savers and are justified from this standpoint, yet it is not necessary to drive with a direct-current motor.

2 The references in Par. 4 and Par. 57 to geared-head machines or tools equipped with mechanical speed variation hardly do justice to these tools, as the speed-changing mechanism in many of them is

as available and handy as if obtained electrically and, therefore, removes the necessity for individual drive for a tool located in a department group. There is no question that, from a commercial viewpoint, the alternating-current motor is preferable for constant speed work, on account of economy of transmission, the ease of obtaining proper voltage for lighting, and the general upkeep of motors. As an example of this latter point, the case of a large manufacturing concern in the middle west is pertinent. The shop is provided with both direct and alternating-current motors, and the cost of upkeep is $2 per month more for the 600 h.p. in direct-current than for the 4000 h.p. in alternating-current.

3 For railroad shop conditions 75 per cent of all requirements can be fully met by constant-speed motors and as the necessary 25 per cent of direct-current motors for the variable speed machines can be obtained by the use of a motor-generator, it would seem that this is the most desirable combination to use. By providing a synchronous motor for driving the motor generator, an excellent opportunity is given to adjust or to increase the power factor, thereby eliminating the low power factor and its consequent disadvantages. The synchronous motor, besides delivering leading current and neutralizing a low power factor, has 70 per cent of its capacity available for mechanical load, and as this part of the load can be utilized to supply the necessary direct-current for variable speed tools, the combination becomes an efficient one. Alternating-current motors are especially economical and advantageous in wood-working shops on account of the presence of dust and flying particles. If direct-current motors are used, the fire hazard necessitates the use of enclosed motors, which are much larger for a given output, on account of the restricted ventilation due to enclosing.

4 As an illustration of the advantage of reckoning with the intermittent duty of a given machine in determining the size of motor to select for a given service, suppose the requirements are 50 h.p. for five minutes, 10 h.p. for ten minutes, the cycle to be repeated every 15 minutes with speed constant. The speed characteristics of the motor require a shunt excitation, i.e., a definite exciting current in the fields regardless of the load on the armature. The average motor load is

$$\begin{aligned} 50 \text{ h.p.} \times 5 \text{ min.} &= 250 \text{ h.p. min.} \\ 10 \text{ h.p.} \times 10 \text{ min.} &= 100 \text{ h.p. min.} \\ \text{Total, } &350 \text{ h.p. min.} \end{aligned}$$

$$\text{or, } \frac{350}{15} = 23.3 \text{ h.p. average.}$$

5 The average load will not produce the heating that the cycle will, for the reason that the copper loss varies as the square of the current. The root mean square or equivalent heating will be produced by the following:

$$\begin{aligned} (50)^2 \times 5 \text{ min.} &= 12{,}500 \text{ h.p. sq. min.} \\ (10)^2 \times 10 \text{ min.} &= 1000 \text{ h.p. sq. min.} \\ \text{Total, } & 13{,}500 \text{ h.p. sq. min.} \end{aligned}$$

Dividing this power by 15 minutes gives the average square as 900, which is equal to 30 h.p.

$$\sqrt{\frac{13{,}500}{15}} = 30 \text{ h.p.}$$

This is the root mean square load, or a load which will produce the same heating if applied continuously as would the intermittent work.

6 Group driving, employing relatively short main and countershafting is not an unmixed evil for the reason that the aggregate stored energy of pulleys, due to flywheel action, is advantageous where slotters, shapers, drills, planers, etc., are present, counteracting in a large measure the shaft friction losses. Very often a better load factor is obtained from the group motors than from the aggregate intermittent service of the individual drive motors. The repairs on individual drive motors are heavier than for the same number of group drive motors. As an illustration, a certain shop has the same number of motors as one of 70 per cent greater capacity located in another city, both shops producing the same kind of output. In the former case individual drive is the rule; in the latter group driving prevails. The repairs per unit of output is larger in the former than in the latter.

7 It is also quite necessary to consider the work to be performed by a given tool in a given department, rather than the range of the tool. For example, a 72-in. boring mill has an ultimate range of work from 72 to 3 in., and with various materials a cutting-speed range of 15 to 25 ft. per min. The total speed range therefore becomes

$$\frac{72 \times 25}{3 \times 15} = 40 \text{ to } 1$$

Where the variety of work a tool will perform is the determining factor a wide range of speed quickly obtained is desirable, but under ordinary machine shop conditions, volume of output is the standard governing the selection of a tool, requiring in many cases constant speed.

8 The ideal condition is when the work is so classified and arranged that the machine is practically performing the same work all the time, i.e., duplication of parts. This condition requires the minimum amount of speed manipulation, at least that which is electrically obtained. The more variable speed is sought for, the further we are getting from ideal conditions. This should promote judicious conservatism and careful analysis to make sure of definite reasons for departure from the ideal standard. A careful study of each tool, with reference to the work to be performed, will establish definite ranges of speed, which will be found quite narrow, and which automatically determine the power requirements. The selection of the driving motor would be governed by the foregoing conditions, and might not apply to the same kind of machine in another shop or even in another department of the same shop, where a different output prevailed.

9 Mechanical changes of a simple character, not covering a very wide range but grouped about the zone of work for which the tool is generally intended or selected to perform, giving changes within comparatively narrow limits, provide variations that are useful and advantageous. This avoids the necessity of using motors with large speed ranges and very often admits of the application of a constant-speed motor, where otherwise a variable-speed motor might be required, all of which tends towards economy in first cost and repairs.

10 The results of comparison vary, depending upon whether the tool output is based on performing stunts or ordinary commercial shop operations. In forge shops at steel plants, where no attempt is made to forge close to size and the machine tools are relied on quickly to reduce the forgings to rough-finished sizes, or where motor shafts are rough forged and then finished on machines, the question of high-speed cutting tools and powerful machines is of the greatest importance. But in railroad shops where the companies purchase driving axles, crank pins, piston rods, etc., rough-turned with a flat-nosed tool to within one-eighth or one-sixteenth of an inch of finished dimensions, an entirely different standard necessarily governs the rating of tools, both as to power and speed requirements. For instance, in a list of parts, 23 in number, scheduled for manufacture at the central or main shop of a large railway, the arrangement is such that the minimum amount of machine work has to be performed at the local or division shop where the repairs are to be made. Piston rods are finished except piston and crosshead fits, crank pins are finished complete except for wheel fit, etc., all of which goes to show that a large quantity of work, at least in railroad shops, requires minimum rather than maximum machine tool duty.

11 The heavy type of so-called high-speed lathe is practically built for forging lathe conditions and under these conditions requires high power to drive, but when, as is frequently the case, this same tool is installed in a railway shop where much smaller cuts are the rule, it is not necessary to provide for such great power, as the full capacity of the tool is never utilized.

12 In order to utilize the full power of such a machine, it is necessary to raise the cutting speed in the same proportion as the area of the cut is reduced, but this is not always possible. For example, a $\frac{3}{8}$ in. by $\frac{1}{8}$ in. cut was taken at 38 ft. per min., while with a cut of $\frac{3}{16}$ in. by $\frac{1}{8}$ in. only 52 ft. per min. could be obtained. With one-half the area of the cut, the cutting speed could be increased only one-third, resulting in the removal of only 57 per cent as much metal. If the full capacity of the machine is not possible, why pay the price for a high power motor when a saving in first cost is possible by the selection of a motor more suitable and a better efficiency can be obtained by running the motor more nearly up to its normal capacity? A 10 per cent loss in efficiency on a 15-h.p. motor capitalized at 10 per cent per annum would amount to $750. The same policy carried out among a large number of machines would result in a considerable saving.

13 The formula in Par. 5 of Appendix No. 2 can be simplified and made more workable if stated as

$$\frac{\text{diameter} \times \text{r.p.m.}}{3.82}$$

This affords a very expeditious method of finding by the slide rule the cubic inches of metal removed per minute, which equals diameter $\times$ r.p.m. $\times$ 3.15 depth by feed. Substituting the values given we have $5.5 \times 45 \times 3.15 \times 0.45 \times 0.06 = 21$ cu. in.

Gano Dunn.[1] It is not a question of whether or not we should have electric motor drive in a machine shop, but what kind of drive. If what Mr. Hess said is true, most of us are wrong, yet I think I am within the facts when I say there are very few machine shops built today that are not electrically driven. If we adopted Mr. Hess's methods of equipping a factory, we should have the conditions shown in Fig. 1 of Mr. Riddell's paper. It is obvious that his form of machine shop is obsolete.

2 After all, the cost of power in our plants is not the principal ques-

[1] Vice-President, Crocker-Wheeler Co., Ampere, N. J.

tion. Some years ago I gathered figures which showed that the cost of power in the average machine shop was only about two per cent of the value of its product. That indicates that questions of saving in power are of minor importance.

3 With Mr. Hess's suggestion, where should we come out on the other vital part of the question, the capacity or output? The day of the electric motor in a machine shop is the day of the red-hot chip. It has driven out belts in the same way that it has driven horses from the front of street cars. It is successful, it is practicable, and it is the one thing that fills all our wants, because it gives us all the power we want, where we want it, when we want it, and as we want it.

4 Mr. DeLeeuw's paper and Mr. Robbins' paper are dictionaries of the art of electric driving. In connection with the classic paper of Mr. Taylor, On the Art of Cutting Metals, we now have a reference library to which we can turn for almost any question likely to come up.

5 I do not believe there is any specific rule that can be laid down to guide an engineer in the layout of a machine shop. Each case must be decided on its own basis. My view of how much power it takes to run a particular machine tool is that it depends on who is the superintendent of the shop. The problem is principally one of capacity. The enormous capacity we can put into a tool by means of the electric drive, to say nothing of all the other advantages that have been rehearsed, it seems to me not only settles the question now, but will continue to settle it.

6 In the very early days, when it was hard to get the attention of manufacturers to the subject of the electric drive, we had to use the argument that it saved power. Then there came a time when it was admitted that electric motors were good for ordinary work, but could not drive rolling mills. And now the climax of rolling-mill development is capped when we see a 6000-h.p. induction motor driving the mill at Gary. I feel that we have now closed the first chapter on the art of the electric drive in machine shops.

Fred. L. Eberhardt, Vice-President of the National Machine Tool Builders Association, gave a summary of the progress made toward the standardization of motors for machine tools by a committee from his association in conference with one appointed by the American Association of Motor Manufacturers. Fifteen points were proposed for discussion by the former committee, of which seven were agreed upon and have since been adopted by the motor manufactures. The remaining eight are still being studied and discussed. The following

quotations from the report of the committee on standardization of motor drives for machine tools to the Rochester convention of the National Machine Tool Builders Association, May 24, 1910, outlines the present situation:

1 *Horse-Powers.* It is thought that the following horse-powers will meet practically all the requirements of electric drives for machine tools: 1, 1½ (for D. C. only), 2, 3, 5, 7½, 10, 15, 20 and 25. Though it was agreed that horse-powers more than 25 and less than 1 are used, it was not thought advisable to embody them at the present in the attempted standardization, but it was held out that they might be embodied some time in the future among the standardized sizes.

2 *Voltage.* It is recommended that for D. C. motors 115 and 230 volts be adopted as standard, and for A. C. motors 110 and 220 volts. There is now a good deal of confusion as to voltages for D. C. motors. The motor manufacturers have reached an agreement among themselves as to these voltages, and the 115 and 230 voltages recommended by them represent the nominal voltage of the system, and not the real voltage at the motor.

3 It is recommended that the horse-power ratings for machine-tool drives be the standard ratings of the American Association of Electric Motor Manufacturers, i.e., (*a*) that motors be given the continuous constant horse-power rating where approximately standard load conditions exist; (*b*) for adjustable-speed motors used for intermittent service the standard two-hour continuous-duty rating be used for ordinary shop conditions and that the name plates of such motors indicate the time as well as horse-power ratings of the motor, and further that the horse-power be figured at the high as well as the low speed for adjustable speed service.

4 *D. C. Motors.* It is the recommendation of the joint committee that constant speed motors, adjustable speed motors with a range of 2 to 1, and adjustable speed motors with a range of 3 to 1, be included in the attempt at standardization. This does not exclude the occasional use of motors with a different speed range, such as 4 to 1, or even more; but it was the opinion of the committee that motors with a higher range of speed than 3 to 1 are not used to a sufficient extent and are not so absolutely necessary for machine-tool construction as to include them among the standardized motors.

5 The following table of speeds is recommended as the standard for adjustable speed D. C. motors:

h.p.	2 : 1	3 : 1
25	900—450	900—300
20	900—450	900—300
15	1200—600	1200—400
10	1200—600	1200—400
7½	1200—600	1200—400
5	1200—600	1200—400
3	1500—750	1500—500
2	1500—750	1500—500
1½	1500—750	1500—500
1	1500—750	1500—500

6 *A. C. Motors.* It is recommended that the following table of polyphase 60-cycle A. C. motors be adopted:

25 h.p.	900 and 600	5 h.p.	1200
20 h.p.	900 and 600	3 h.p.	1200
15 h.p.	900 and 600	2 h.p.	1200
10 h.p.	1200 and 600	1 h.p.	1800 & 1200
$7\frac{1}{2}$ h.p.	1200 and 900		

7 For the consideration of the constant-speed A. C. motors, 60 cycles is to be used as the basis.

8 *Shaft Diameter.* It is recommended that the shaft diameter be figured according to the formula $D=C\sqrt{\frac{\text{h. p.}}{S}}$ in which C is a constant to be agreed upon by motor manufacturers, D the diameter, and S the speed; it is further desired that all diameters up to and including one and one-half inches be given in one-eighth of an inch, and all diameters above one and one-half inches be given in one-quarter of an inch.

9 *Length of Shaft.* It is recommended that there shall be a fixed proportion between diameter and length; the constant to be determined by the motor builders. Further, that the shaft be rounded at the end.

10 *Keyways.* It is recommended that keyways be made for square keys and that the key be equal to one-fourth the diameter of the shaft.

11 *Driving Fit.* It is recommended that there be added to the standard dimensions of the shaft 0.0005 in. for every half inch diameter of the shaft or fraction thereof.

12 *Variation.* It is recommended that shafts shall not be under the specified size, but may exceed same by 0.0005.

13 *Height of Centre.* The height of centre to be given in full one-fourth inch, and shall not be less than figured dimension, but may exceed this dimension by one thirty-second.

14 *Clearance Circle.* It is recommended that the clearance circle around the motor shall have a diameter of one-half inch less than twice the centre height.

15 *Base.* All motors to be held down by four bolts. Bolt holes to be drilled one-sixteenth above size of bolt required. Bottom of motor to be planed parallel with the shaft of motor. It is further recommended that the bolt holes be placed in a configuration of constant proportions, preferably in a square, and that the dimensions of this configuration be made a function of the horse-power divided by the speed, and further that all dimensions be given in the nearest higher one-fourth inch. The feet of the motor should extend beyond the body sufficiently to allow for drilling and reaming of dowel pin-hole while motor is in place.

A. L. DELEEUW. Generally speaking, the machine tool builder does not know to what purpose his product will be applied by the consumer. It is true he knows in a general way that a lathe will be used for turning and a drill press for drilling, but he has no knowledge of the methods employed in the shop where his product is to be used, nor whether

his machine will be used for general work or for some special operation. The machine may never be called upon to work up to its maximum capacity and yet it may be called upon to do this all the time. If the machine is to be supplied with a motor, the only safe thing is to attach a motor of sufficient capacity to run the machine all the time up to its maximum output. Even if it is known that the machine will be used for light work by the man who buys it, yet it may some time come into other hands and be used for entirely different purposes. Hence, unless the machine is supplied with a sufficiently large motor, the design may be condemned at some time.

2 It is true in general that machine tools do not operate at their maximum capacity or even at the rated capacity of the attached motor more than one-third to one-fifth of the time, so that in the majority of cases a much smaller motor can be used than would be required if the machine were constantly working at full capacity. However, the machine tool builder has no guarantee that this general rule will apply to his machine. The tendency nowadays is to specialize in the use of machine tools and to subdivide operations in the shop. Whereas a few years ago it was the custom to give a shaft to some lathe hand to be turned and let him finish all operations on this shaft, preferably in one setting, now it is more common practice first to rough a lot of shafts, then finish them in a subsequent operation, and then perhaps grind them for a final finish. Wherever it is possible to do so, these operations are again subdivided.

3 The subdivision of operations, when carried out to its limit, makes operations in the shop extremely simple, requiring no adjustments of feeds or speeds while a lot is run through the machine and calling for only a single tool. Where operations are carried through in this manner it is often possible to make them continuous. By this is meant that the process is so arranged that both machine and man are working all the time, or at least practically so. The vertical milling machine, for instance, in milling flat surfaces, may do so with the use of a rotary table and a multiple fixture mounted on this table whereby it becomes possible for the operator to load and unload one piece while the cutter is acting on another piece. In this case the feed is adjusted to such a rate that the operator has just time enough to load and unload while the cutter passes over one piece. Where the piece is so small that the time for cutting is materially less than for loading, more than one operator may be used on such a machine; where it is much more than for loading, one operator may attend to two or three machines. In all cases the highest attainable economy

is reached when both operators and machines are working all the time and it should be kept in mind that the rate of work should be such that the machine can keep it up without breakdown, and that the tool will not need an excessive amount of regrinding, nor the operator be fatigued by too rapid work.

4 Though the example given above is perhaps the most perfect application of this system of continuous operation and though rotary fixtures cannot always be applied, there are various means by which this same degree of efficiency can be approximated. The table of the milling machine may be given a reciprocating motion, either automatically or by the hand of the operator, at the end of each cutting stroke. In this case two fixtures are used. Again, a single fixture may be used with two loading fixtures which can readily be clamped in the stationary fixture on the table of the milling machine, so that only a very small amount of time is lost between cutting operations. The relative cost of labor and machine burden would determine whether it would be better to slow the feed down so as to give the operator time to load a fixture or whether two operators should be employed for one machine.

5 The same degree of efficiency can often be reached in lathe operations by providing the operator with two mandrels and dogs and shading the cutting operations down to a point where the time of cutting is just slightly longer than the time for removing a piece from one mandrel and loading a new one. Here again two operators may be employed or one operator may run two machines. There are many cases where the time of the cutting operation is considerably longer than the time required for preparing a new piece for the machine. In such cases it may often be found advantageous to divide the cutting operation into two parts so as to have the time for cutting more nearly equal to that for loading. In a similar way, efficiency on the grinding machine can often be reached by grinding in two operations, one rough and the other for finish. Drilling also lends itself in many cases to the application of this plan, especially where gang drills are used.

6 The application of this principle of keeping both machines and operators busy all the time at their maximum efficiency leads to many interesting problems in the machine shop and could be carried very much further than is done at the present time. The application of this system, however, imposes much heavier duty on the machine tool and would not allow, therefore, of applying to such tools motors which have been rated on the assumption that they will not be called upon for more than two hours continuous service.

Carl G. Barth. The various advantages of motor drives over belt drives have been thoroughly and ably set forth, but I cannot let go unchallenged the claim of closer speed regulation.

2 While speed controllers of motors are frequently arranged to give successive speeds varying nominally by as little as 5 per cent, the variation in speed consequent on a variation in load is so great as to make it practically impossible to tell beforehand what controller point must be used to insure a predetermined cutting speed for a given piece of work, as required by the most advanced shop management of today.

3 As an exponent of such management I have therefore been forced to remain an advocate of belt drives in preference to individual motor drives; for if a belt is properly cared for and not required to transmit an undue amount of power, its speed variation with load variation is only a fraction of that of an individual motor under the same conditions.

4 This does not mean that I never advocate individual motor drives, for frequently the real advantages of such drives are so great as to outweigh entirely the consideration of the greatest constancy of speed. I hope the time is not far away when motors will be built at a reasonable cost that will be so nearly constant in speed at all controller points, regardless of load, that they will possess incontrovertibly all the advantages claimed for motors in the papers before us.

5 In fact, I have recently learned of a company that expects soon to put on the market a line of 3 to 1 adjustable-speed motors with no greater variation then 4 per cent in any part of the entire range of speeds and loads. If these motors actually materialize, a great step will have been taken towards the millenium of the machine shop engineer vitally interested in cutting speeds. But nothing is yet in sight that promises entirely to replace the belt.

John Riddell. Ball bearings are undoubtedly very valuable, but nothing has been said about the quantity of belts required to go with lineshafting in an establishment like the General Electric Company. I pointed out in my paper by very conservative figures that had we continued putting in lineshafting, countershafts, hangers and belts, we would use approximately $6\frac{1}{2}$ miles of lineshafting, about $4\frac{3}{4}$ miles of countershafts, 21,225 hangers, and about $80\frac{1}{2}$ miles of belts. These figures were based on 8500 machine tools. We have in addition to this number possibly 2000 other machines, most of which are driven by motors. These would require many additional feet of shafting and

belts, and a great many more hangers or roller bearings. We know from many years experience that the upkeep and attention required by such material is very great.

2 Machine tool builders seem to think that every electric motor is made for some machine tool, whereas less than 3 per cent of the motors turned out by the General Electric Company are used for this purpose. If the tool builders would standardize their tools so that the same motor would do for the same nominal size of lathe, milling machine, or any other machine tool, the results would be more satisfactory. It would be useless for us to undertake to standardize 70,000 or 80,000 motors when only about 2000 of them would be used for machine tools and these widely distributed over many types. It would not pay any concern turning out electric motors to attempt to standardize for machine tools, especially since they are rapidly being changed and developed. Many machine tools are made to double the work today that they did a few years ago, and had motors been standardized then they would have undergone constant changes. I speak from the standpoint of the middleman, being partly an electrician and partly a mechanician, and knowing the difficulties from both sides.

H. A. Hornor.[1] In a plant which requires a number of tools of large size for operating blacksmith, plate, angle, forge, pattern and joiner shops, the machine shop bears a less important relation to the total power consumption. For the operation of this class of tools constant-speed motors with heavy starting torque, capable of withstanding prolonged overloads, are satisfactory, as the work does not require close adjustment of speed. With an ample power supply of alternating current the losses are reasonably low and are due in large part to the variation of the product. Under these circumstances the induction motor can be used with great economy. It is thrown on the line and reversed with a simple knife switch, requiring no starting compensator and permitting quick stopping and reversing. The induction motor, if substantially designed, will withstand all the shocks which severe duties demand and will give little trouble or expense. A 50-h.p. squirrel-cage induction motor has operated a jogging machine for ten years with no other attention than the oiling of the bearings. The plant just mentioned was equipped with induction motors at the time when the individual motor drive was an experi-

[1] New York Shipbuilding Co., Camden, N. J.

ment and it may be conservatively stated that after a decade it has fulfilled every promise which its advocates claimed at its installation.

W. S. Chase.[1] With reference to the statement in Par. 82 of Mr. DeLeeuw's paper that variable-speed motors should always be used with screw machines, our company has had on the market for two years an automatic screw machine, usually driven by a single belt, all the speeds necessary for the production of any part being controlled within the machine beyond the point of application of power. For electric drive it is merely necessary to supply a motor instead of a belt and the motor may be of any type, alternating or direct-current, of any standard make, and of constant speed. We believe that we were the first to adopt this self-contained single drive on the automatic screw machine, although similar machines have recently been placed on the market.

Clarence L. Collens, 2d.[2] I will limit myself exclusively to adjustable speed-direct-current motors and certain phases of their use in manufacturing machine shops, where the variable-speed machine tool plays an important part in the process of manufacture.

2 *Flexibility of Speed Control.* In order to deal with definite figures instead of general statements Table 1 is submitted. This table is intended to give an idea of the average speed adjustments possible with belt-driven tools, or with gear-box-driven tools using constant-speed motors. By belt-driven tools is meant tools having cone pulleys for speed control. Six representative tools are shown, with a total range of spindle speeds or cutting strokes, indicated for each, which I believe not only represents a fair average of the speeds for which such tools are now designed, but also fully covers all the requirements of the class of work for which each is intended. In the case of the lathes, two different ranges are shown, as it is hard to give a single ratio which will fairly represent all makes and classes.

3 Under both the belt-driven tools and the gear-box tools, columns A and B represent, respectively, the minimum and the maximum number of speed changes found in standard tools of the types shown. In each case both the number of changes and the percentage jump in speed at each change are shown, assuming that the speeds are in geometrical progression. The average practice is more nearly repre-

[1] Manager of Sales, National-Acme Mfg. Co., Cleveland, Ohio.
[2] President, Reliance Elec. and Eng. Co., Cleveland, Ohio.

sented by column A than by column B. In some cases the maximum number of speed changes for the belt-driven tools is greater than for the gear-box types, due to the use of countershafts arranged for two and in some cases three speeds.

4 Compare the figures indicated in the table with the results which can be obtained by using adjustable-speed direct-current motors. With the speeds in geometrical progression and a controller having 20 contact points for speed adjustment. The jump in speed between each step for motors with 1:2, 1:3 and 1:4 speed ratios will be 3.7, 6.0

TABLE 1 SPEED CHANGES ON TYPICAL MACHINE TOOLS

	Spindle Speeds or Cutting Strokes Per. Min.		Belt-Driven Cone Pulley Types				Gear-Box Types using Constant Speed Motors			
			A		B		A		B	
	Total Range	Ratio	no.	per cent	no.	per cent	no	per cent	no.	per cent
24 in. Engine Lathe	3.5-350	1:100	10	66.8	24	22.2	8	93.0	12	52.0
24 in. Engine Lathe	10-360	1:36	10	48.9	24	16.9	8	66.8	12	38.5
4 ft. Radial Drills	20-320	1:16	8	48.6	16	20.3	12	28.6	24	12.8
No. 3 Plain Miller	12-360	1:30	12	36.2	18	22.2	8	62.6	18	22.2
42 in. Vertical Boring Mills	2- 60	1:30	10	45.9	20	19.6	10	45.9	15	27.5
24 in. Crank Shaper	6- 96	1:16	8	48.6	8	48.6	8	48.6	10	36.1
21 in. Drill Press	12-300	1:25	8	58.4	8	58.4	8	58.4	16	23.9
Average percentage jump at each speed change				50.5		29.7		57.7		30.4
Average percentage which cutting or peripheral speeds must necessarily be below maximum if each tool is doing a large range of miscellaneous work				25.3		14.9		28.9		15.2

and 7.6 per cent respectively. With the armature-shifting type of adjustable speed-motor there is of course no jump, the speed change being continuous.

5 From this definite comparison it is almost self-evident that there will be many conditions of work under which the use of the adjustable-speed direct-current motor will result in an increase in the productive capacity of the machine tool of at least 5 per cent, and in many cases 10 per cent as compared with any form of group or constant-speed gear-box drive. In many cases the greater accuracy of

speed adjustment will in itself produce such an increase, and when there is added the greater ease and convenience of making the speed change, the probabilities are more than doubled.

6 In large manufacturing machine shops using specialized tools and limiting each tool to practically single operations with very little change in the size and character of the work on each tool, the question of accurate speed adjustment is of lesser and in some cases no importance, but this is not true of the medium-sized or comparatively small plants. In such plants there is not enough work of any one character to justify a specialized tool, and in consequence each tool of the variable-speed variety is called upon to work continuously over a wide and miscellaneous range of work. Does a 5 per cent increase in productive capacity justify for work of this character the use of the individual adjustable-speed motor?

7 In a small or medium-sized manufacturing machine shop, the average maximum power requirements per tool will usually run well under 5 h.p. Taking 30 cents per hour as the average rate of pay and 30 cents per hour as a fair and probably low overhead charge per tool, the total expense per tool per year of 3000 hours amounts to $1800. Using this figure, 1 per cent increase in productive capacity means an annual saving of $18 per tool.

8 Even taking into account the much lower capacity per tool of the group-drive motor, the difference between the cost of any form of group-drive installation and the individual-drive adjustable-speed motor, including the cost of mounting on the tool, will in some cases be as low as $200 per tool and will rarely exceed $350 per tool in a plant of the size under consideration. Assuming 15 per cent as the rate of interest and depreciation, an increase in productive capacity of from 1.7 per cent to 2.9 per cent will capitalize the additional investment, and from 11 to 20 per cent will pay for it in one year.

9 Even assuming that the plant rents power from some central station and is on the outskirts of a city where only alternating current is available, the additional cost of the motor-generator set will run from $30 to $60 per tool, depending on the size of the plant and the number of variable-speed tools. With the 5-h.p. maximum motor capacity per tool, the generator capacity will be about 2 kw. per tool. An increase in productive capacity of from $\frac{1}{4}$ to $\frac{1}{2}$ per cent will capitalize the motor-generator investment and from 2 to 3 per cent will pay for it in one year.

10 The total additional cost of the direct-current motors and generators, even taking the maximum figures given, will thus be capi-

talized by $3\frac{1}{2}$ per cent increase in productive capacity. Five per cent increase in output means a saving equal to practically 25 per cent of the additional cost of the investment, whereas 10 per cent pays for the change in two years.

11 These figures are well within the possibilities of attainment. It is assumed, however, that the plant is crowded for work and is in a position to sell the additional output. This is a fair assumption, as I believe a plant which is not working full capacity would not be apt to consider any change in its power equipment. As Mr. DeLeeuw has said, an increase in the amount of chips per hour is a more vital factor than any relative saving or loss in different methods of transmitting power.

12 *Speed Ratios for Direct-Current Adjustable-Speed Motors.* In Appendix No. 3 of Mr. Robbins' paper, he has in all cases shown 1:3 as the ratio for adjustable-speed direct-current motors. I agree with Mr. Robbins that this will probably become the ultimate standard for many classes of machine tools, but I do not feel that it will ultimately become the standard for all classes, nor does it lend itself entirely to current designs.

13 The choice of the proper speed ratio for an adjustable-speed motor resolves itself into a very careful study of the ratios of the different gear changes for which the tool is arranged. In the case of engine lathes a motor of 1:3 or even 1:2 speed ratio is usually wholly satisfactory, due to the fact that more attention has probably been given to the application of motors to lathes than to any other tool, and in the designs of motor-driven lathes there are always a sufficient number of gear changes so that the jump in speed between gear changes is rarely more than 200 per cent and is therefore completely covered by an adjustable speed motor of 1:3 speed ratio. This also applies to millers, radial drills, boring mills, etc., with double instead of single back gears.

14 There are, however, a large number of tools, including many millers, boring mills, radial drills, drill presses, shapers, etc., which when belt-driven have merely a cone pulley and a single back gear. When an adjustable-speed motor is applied to such a tool, as a rule it merely takes the place of the cone pulley and no change is made in the back-gear ratio, which is seldom less than 1: 4 and is in many cases greater than 1:6. In consequence, there are many tools on which the use of motors with 1:4, 1:5, or 1:6 speed ratios is not only wholly practical but is more economical from an operating standpoint in all cases where accurate speed control is in any way essential. Unless a motor

is used whose range of speeds has the same ratio as the back gear, there will be a jump or gap of more or less greater magnitude right in the center of the entire range of spindle speeds. It seems illogical to provide close speed adjustment over part of the range and not to provide it over all.

15 Take a tool with eight spindle speeds in geometrical progression from 20 to 320 r.p.m., obtained with a four-step cone pulley and a single back gear. Without going into the theory of geometrical series, the ratio from the first to the fifth speed in this series is practically 1:5. This fixes the ratio of the back gear for the cone-pulley type of tool. If a 1:3 motor is used with this same back gear, the speeds obtained are 20 to 60 r.p.m. with the back gear in and 100 to 300 r.p.m. without the back gear, leaving a jump of 67 per cent between the two series. As speeds below 40 r.p.m. and above 200 r.p.m. are probably not used more than 10 per cent of the time, this means an important break in the center of the active range. This jump may not look very serious with a 1:5 back-gear ratio, but in many cases the ratio is 1:6, meaning a jump of 100 per cent.

16 In this same case a 1:5 motor would give speeds from 13 to 64 r.p.m. with the back gear in and from 64 to 320 r.p.m. without, leaving no jump or break in the entire range. A still more satisfactory arrangement would be obtained if the tool manufacturer changed the ratio of his back gear from 1:5 to 1:4 when furnishing his standard tool with motor drive. If this is done, a motor with 1:4 speed ratio is just as satisfactory as the 1:5 motor, gives an unbroken range of spindle speeds, and is less expensive. The range of spindle speeds then becomes 20 to 80 r.p.m. with the back gear and 80 to 320 r.p.m. without.

17 I would not make this criticism if the machine tool manufacturer made a practice of changing the ratio of his back gear when furnishing certain standard belt-driven types of tools equipped for drive by an adjustable-speed motor. There are many tools, with single back gears whose total range of speeds is 1:16 or slightly greater and to which the addition of a second gear change for motor drive would add unwarranted expense. In most cases a change in the ratio of the back gear would add practically no expense, would simply mean a few additional stock gears for the manufacturer, and would make a motor-driven unit which is much more satisfactory to the purchaser. A motor with at least a 1:4 speed ratio should be used on these tools.

18 A motor of at least 1:4 speed ratio is also desirable on any variable-speed tool which, when belt-driven, is provided with no

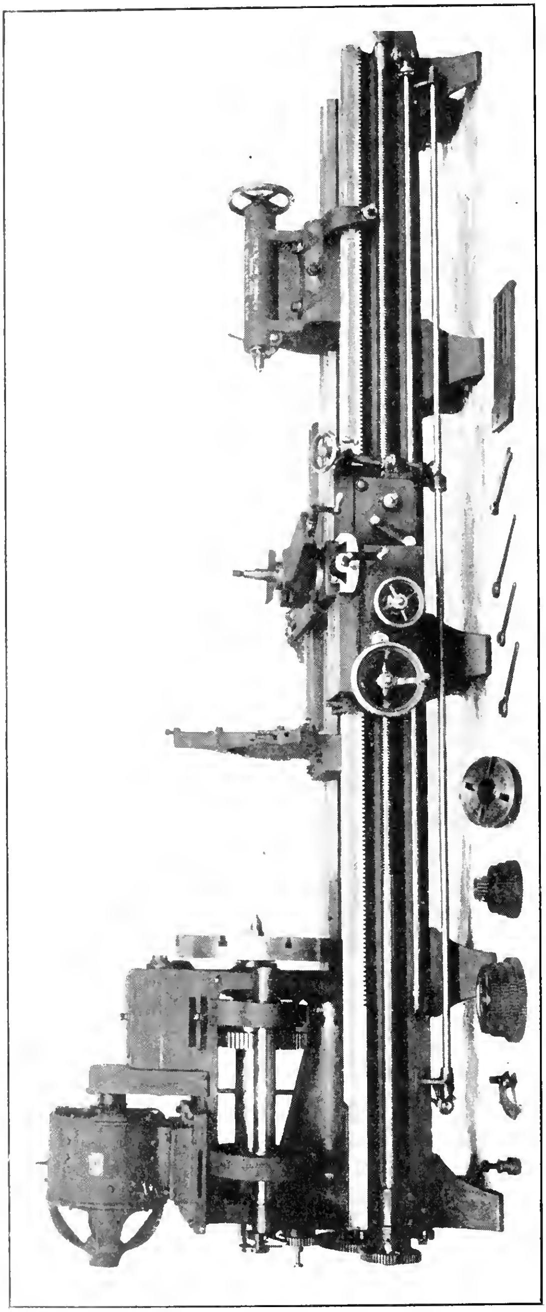

Fig. 1 Application of Armature-Shifting Motor to a Lathe

back gears. Slotters and some types of bolt machinery come in this class.

19 On certain specialized tools a consecutive range of spindle speeds with graduations not exceeding 5 per cent is not always necessary. Take for instance a driving-wheel lathe, used almost exclusively on two diameters of work, the outer tire and the finished spots

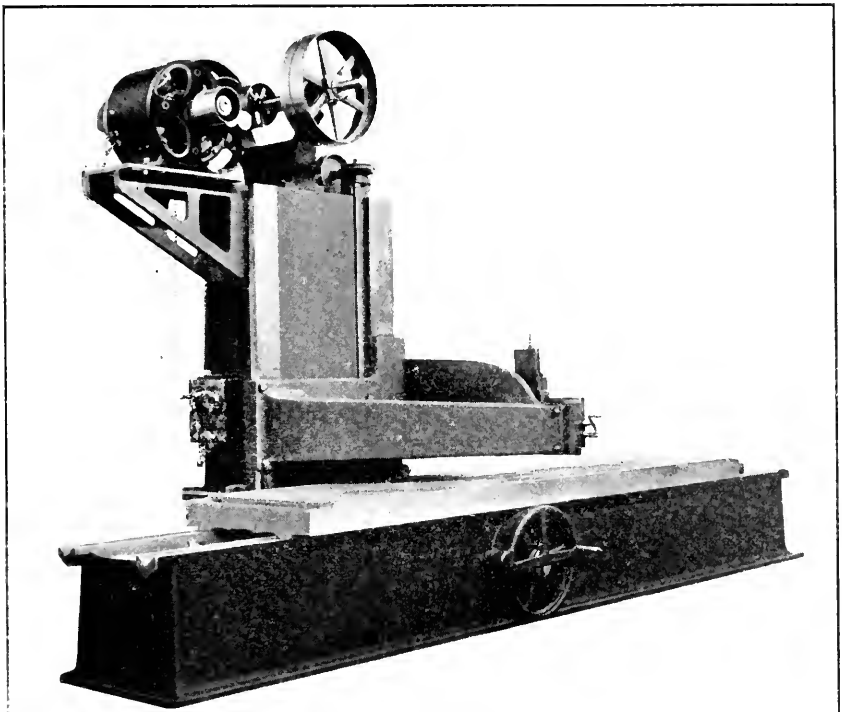

FIG. 2 ARMATURE-SHIFTING MOTOR APPLIED TO A PLANER

on the axle for the bearings. A single back gear, taking into account the difference in the diameter of the axle and tire, as well as the difference in the materials of which these are made, and a motor of 1:2 speed ratio would be wholly satisfactory, even though this left a break of over 200 per cent in the center of the entire range of spindle speeds.

20 *Applying Motors to Old Belt-Driven Tools.* Another field for a motor of at least 1:4 speed ratio is in conversion to motor drive of

old belt-driven tools. The majority of there have merely single back gears and the ratio is rarely less than 1:6. In changing many such tools for motor drive, especially the smaller and medium-sized machines, it is not only simpler but in many cases less expensive to to use a wide-range motor rather than to install additional gear changes.

21 Take for instance the headstock drive shown in Fig. 18 of Mr. Fair's paper. I feel sure that the single back gear in this lathe had a ratio of at least 1:9. If a motor 1:3 were used without additional gear changes there would be a jump of 200 per cent in the center of the entire range of spindle speeds. Mr. Fair prevented this gap in the speeds by using a 1:3 motor with two gear combinations between the motor and the quill which replaced the former cone pulley. The ratio between these two combinations of gear drive was probably 1:3, giving a total range of speeds to the quill of 1:9, so that there was no jump or break between the range of spindle speeds obtained from the quill direct and the range obtained through the back gear.

22 If in such cases a 1:6 motor is used and the ratio of the back gear is changed from 1:9 to 1:6, the drive from motor to the quill can be made direct, either by silent chain or with an intermediate gear, doing away entirely with the change gears, extra shafting and bearings. This gives a total range of spindle speeds of 1:36 without any break, which fully covers most requirements on lathes up to 24 in.

23 It is a very simple and inexpensive matter to change the sizes of two gears on shafts already in place, with bearings and supports already provided. To change the ratio of the back gear from 1:9 to 1:6, it is merely necessary slightly to increase the diameter of the pinion at the back end of the cone pulley or quill, decreasing correspondingly the gear with which it meshes on the back-gear shaft. The additional cost of a 5-h.p. 1: 6 motor as compared with a 5h. p. 1:3 motor will not exceed $75, which I believe is fully offset by the more simple application and mounting.

24 *Choice of Series, Shunt or Compound-Wound Motors.* The only change I would suggest in the table of motors for machine tools given on page 618 of Mr. Fair's paper would be to show shunt motors as well as compound-wound motors under shapers, slotters and reciprocating keyseaters. On these tools the maximum load comes during the cutting stroke, which is usually of sufficient duration to have the load reach a constant value. As the return stroke is of less duration than the cutting stroke, there is no chance to utilize a flywheel effect.

25 *Types of Adjustable-Speed Direct-Current Motors.* There are two distinct types of adjustable-speed direct-current motors used for machine tool work, both operating on the same final principle, namely the increase in speed of a direct-current motor with any decrease in the strength of the magnetic field within which the armature rotates. In one type the strength of the magnetic field is varied by the use of

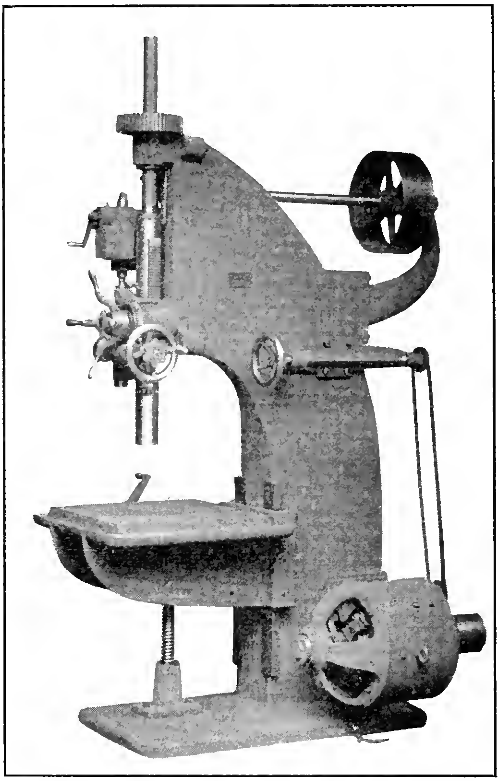

Fig. 3 Drill Press Driven by an Armature-Shifting Motor

resistance in the field circuit, and in the other the magnetic reluctance of the magnetic circuit is changed by sliding a slightly cone-shpaed armature laterally away from its normal position directly beneath the main poles.

26 The characteristics and advantages of the armature-shifting type of motor for machine tool work are briefly as follows:

a No resistance controller is required. The speed control is mechanical, obtained by turning a hand wheel, an operation with which the machinist is thoroughly familiar. This hand wheel can be located at any point convenient to the operator.

b The speed control is a distinct and separate coperation from the starting, stopping or reversing of the motor. Two advantages are derived from this: (1) automatic-type starters can be used, taking entirely away from the machine-tool operator all electrical control of the motor and all possibility of abuse to motors, starting equipment or controllers; (2) when the speed is once set, the motor can be started and stopped as often as is necessary to caliper work or sharpen tools without affecting the speed-setting. In the case of unskilled operators, the speed can be set by a man or speed boss and cannot be tampered with.

c A continuous speed-change is obtained instead of jumping by steps.

d The field distortion due to full-load armature current is practically no greater at high speed under weak magnetic field than at low speed under full magnetic field, due to the fact that under decreasing magnetic field the magneto-motive-force remains constant, the air-gap length is increased and the air-gap area decreased. Satisfactory commutation is therefore obtained over wide speed ranges and is still further augmented for heavy overloads by the use of interpoles.

e Wide speed ranges are secured without excessive cost. These are very often found valuable in applying adjustable-speed motors to machine tools having single back gears, or in converting to motor drive old belt-driven tools.

27 *Methods of Applying Armature-Shifting Motors.* The convenience of speed control with a field-resistance drum-type controller has been well illustrated and is always important from an operating standpoint. Equal convenience can also be obtained in the arrangement of the mechanical speed control of the armature-shifting type of adjustable-speed motor. Fig. 1 shows a 30 in. by 24 ft. engine lathe with the mechanical speed control operated from the crank handle at the right of the lathe apron, the connection to the motor being obtained by means of a splined shaft running along the lathe bed. A second splined shaft operated by a hand wheel, also at the lathe

apron, controls the full-reverse drum-type starter seen on the right at the end of the lathe bed. The two operations are therefore separate but are both controlled from the same point. Fig. 2 shows a satisfactory and convenient method of controlling the speed where the motor is mounted high on the machine tool. This is done by means of a pendent chain similar to that used on chain hoists. Fig. 3 shows a high-speed drill press with the hand wheel for mechanical speed control brought to a point within easy reach of the operator at all times.

28 *Conclusion.* No one type of drive entirely meets all the varying conditions which are found in machine-tool operations. There are many cases where I would recommend belt drive or speed-box drive with either group or individual constant-speed motors. Other conditions require adjustable-speed direct-current motors with field resistance control, while in many others the mechanical speed-control obtained with the armature-shifting type adjustable-speed motor offers advantages which cannot be obtained with any other method of machine tool drive.

GENERAL NOTES

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

The twenty-seventh annual convention of the American Institute of Electrical Engineers was held June 28-July 1 in Jefferson, N. H., with headquarters at the Waumbek Hotel.

Among the papers presented were: Disruptive Strength with Transient Voltages, by Joseph L. R. Hayden and Charles P. Steinmetz, Mem. Am. Soc. M. E.; Vector Power in Alternating-Current Circuits, by A. E. Kennelly; Parallel Operation of Three-Phase Generators with their Neutrals Interconnected, by George I. Rhodes; Interaction of Flywheels and Motors When Driving Roll Trains by Induction Motors, by F. G. Gasche; Electric Locomotive Design, by N. W. Storer and G. M. Eaton; A Method of Determining the Adequacy of an Electric Railway System, by R. W. Harris; Power Economy in Electric Railway Operation—Coasting Clock Tests on the Manhattan Elevated Railway, by H. St. Clair Putnam; Economy in Car Operation, by Cyril J. Hopkins.

THE AMERICAN SOCIETY OF CIVIL ENGINEERS

The American Society of Civil Engineers held its 42d annual convention at the Congress Hotel, Chicago, from June 20 to 24, 1910, with a registered attendance of 540. The main object of the summer conventions of the society is to enable members to meet each other socially and discuss informally matters of engineering interest, and no technical papers were read but those in attendance were given an opportunity to become acquainted with engineering works of importance in and near Chicago.

On the evening of June 21, Alfred Noble, Mem. Am. Soc. M. E., Past-President of the American Society of Civil Engineers, described the New York tunnel extension of the Pennsylvania Railroad, illustrating his description with lantern slides. Illustrated addresses were also delivered on succeeding evenings by J. Waldo Smith, Mem. Am. Soc. M. E., chief engineer of the Board of Water Supply of New York, on the new water supply for that city; and by D. H. Burnham, describing the perfected plans for the beautifying of the city of Chicago.

All day trips were made to Gary, Ind., where the new steel plant was visited; to Lockport by boat down to the Drainage Canal; and to Lake Bluff to inspect the new United States Naval Training Station which it is expected will be completed in October. Other short excursions were made to the Chicago and Northwestern Railway terminal now under construction; to the Fish street power station of the Commonwealth Edison Company; and to the mail order house of Sears, Roebuck & Company.

Reports of committees were also presented during the convention.

OPENING OF FRITZ ENGINEERING AND COXE MINING LABORATORIES AT LEHIGH UNIVERSITY

The John Fritz Engineering Laboratory and the Eckley B. Coxe Mining Laboratory were formally dedicated at Lehigh University on June 11, 1910. The gift of the Engineering Laboratory by John Fritz, Hon. Mem. Am. Soc. M. E., was announced at the 1909 meeting of the alumni and by vote of the trustees has been named in honor of its donor, the father of the steel industry in the United States. The Mining Laboratory was named in memory of Eckley B. Coxe, Past-President Am. Soc. M. E., now deceased, a former trustee of the university and its warm friend.

Robert W. Hunt of Chicago, Past-President of the American Institute of Mining Engineers and of The American Society of Mechanical Engineers, a personal friend of both Mr. Fritz and Mr. Coxe, made the speech of dedication. He reviewed in some detail the remarkable engineering progress of John Fritz, commencing with his start as a blacksmith and including the establishment of the Bethlehem Bessemer Works, which introduced the Bessemer process into this country and is the greatest monument to his fame. Nevertheless, he said, although Mr. Fritz has lived to see eventful developments in science, from the construction and operation of steam to the navigation of the air, and in his own particular field of engineering has participated in the development of a revolutionizing process, he is of the present and building for the future in the establishment of this testing laboratory, made after his own design and constructed under his own supervision.

In speaking of Mr. Coxe, Mr. Hunt said: "It was my good fortune to have him as a friend. To know him was to love him. He had been given all the advantages of education and travel. He inherited great wealth and not only wisely administered it, but, in so doing, built up a large business and brought together a thriving community of people whose welfare he regarded and ministered to as a sacred trust. With all his wealth, education, travel and position, he remained as simple-hearted as a boy."

Both Mr. Fritz and Mr. Coxe served Lehigh University on its Board of Trustees and were deeply interested in its welfare. They were moreover intimate and attached friends, and the dedication of the two laboratories on the same day was therefore most appropriate.

INTERNATIONAL HUNTING CONGRESS

The second International Hunting Congress, which will be held in Vienna, Austria, September 5-7, 1910, intends to give an important place in its deliberations to international technical questions regarding weapons used in hunting. A number of entry forms have been furnished the Secretary of the Society, and may be secured on application.

DEDICATION OF FOREST PRODUCTS LABORATORY

The new Forests Products Laboratory established at the University of Wisconsin with the coöperation of the Forest Service of the United States was for-

mally dedicated Saturday, June 4, 1910, in the presence of representatives of lumber manufacturing and woodworking associations from all parts of the country. Chief Forester Henry S. Graves in the principal speech of the occasion outlined the work to be undertaken in investigating the more effective utilization of forest products.

The laboratory was open in the morning to the inspection of visitors, all the apparatus and machinery being in operation. The experiments which will be carried on will be of great importance to all wood users, and will include the department of wood preservation where the effect of different preservatives will be tested; and departments for tests of the strength and other properties of timber, the saving of wood waste by means of distillation processes; and the fibre of various woods for paper and other purposes.

The building in which the work will be carried on has cost about $50,000 and the equipment, most of which has been brought from the small forestry laboratories formerly maintained by the government at various places, is valued at $100,000 more.

The American Society of Mechanical Engineers was represented at the dedication by Carl Albert Johnson and Prof. T. G. D. Mack.

NATIONAL SOCIETY FOR THE PROMOTION OF INDUSTRIAL EDUCATION

The National Society for the Promotion of Industrial Education has submitted to President Taft a report on the Relation of Industrial Training to the General System of Education in the United States. This report takes the need for more industrial life as a self-evident and long-acknowledged fact, and lays particular stress upon the need for a comprehensive and thoroughgoing statistical investigation with reference to the following points: (1) The needs of the different states and localities for skilled persons in the trades; (2) the character of the curricula and the service of existing industrial and apprentice schools in the United States; (3) the relation of existing industrial schools to the general educational system of their state and of their region; (4) the lessons to be learned from industrial schools in foreign countries. The report recommends that the above investigation be entrusted to the United States Department of Education and that the financial support necessary be furnished by Congress.

SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION

The attendance at the eighteenth annual meeting of the Society for the Promotion of Engineering Education, held in Madison, Wis., June 23-26, 1910, was 149, exceeding that of any previous meeting of the organization.

Papers were presented on Inspection Trips for Technical Students, by Prof. George C. Shaad; The Teaching of Judgment, by Edward J. Kunze, Mem. Am. Soc. M. E.; Inspection Trips of Ohio State University Students, by Prof. Wm. T. Magruder, Mem. Am. Soc. M. E.; Recent Progress in Coöperative Technical Education, Herman Schnieder; Clearness and Accuracy in Composition, J. J. Clark; Character Training, J. P. Jackson, Mem. Am. Soc. M. E.;Technical Education in Germany, Frank Koester; Technical Education in China, W. H.

Adams, Mem. Am. Soc. M. E.; and a symposium on Coöperative Work for the Railroad Commission and Tax Commission of Wisconsin, by Prof. W. D. Pence, J. G. D. Mack, Mem. Am. Soc. M. E., and C. P. Burgess. Dr. George H. Shepard, Mem. Am. Soc. M. E., presented a very full and interesting summary of methods used in German technical universities and a comparison with American methods. The Report of the committee on Engineering Degrees was read by the chairman, Prof. W. F. M. Goss, Mem. Am. Soc. M. E., and after much discussion accepted.

The following officers were elected for the year 1910-1911: President, A. N. Talbot; Vice-Presidents, Wm. Kent, Mem. Am. Soc. M. E., and M. S. Ketchum; Treasurer, Wm. H. Wiley, Mem. Am. Soc. M. E.; and Secretary, H. H. Norris.

AMERICAN SOCIETY FOR TESTING MATERIALS

The thirteenth annual meeting of the American Society for Testing Materials, affiliated with the International Association for Testing Materials, was held at the Hotel Traymore, Atlantic City, N. J., June 28-July 2, 1910, with an attendance of 450. Among the reports and papers presented at the business sessions were: Report of Committee on Standard Specifications for Cast-Iron and Finished Castings, Walter Wood, Mem. Am. Soc. M. E., chairman; Tests of Cast-Iron Arbitration Test Bars, C. D. Mathews; Untruly and Unevenly Chilled Car Wheels, T. D. West, Mem. Am. Soc. M. E.; Report of Committee on Standard Methods for Testing, Prof. Gaetano Lanza, Mem. Am. Soc. M. E., chairman; Report of Committee on Standard Specifications for Hard-Drawn Copper Wire, J. A. Capp, Mem. Am. Soc. M. E., chairman; The Forest Products Laboratory, its Purpose and Work, McGarvey Cline; Tests on Steel and Wrought-Iron Beams, H. F. Moore; Report of Committee on Standard Specifications for Steel, William R. Webster, Mem. Am. Soc. M. E., chairman; Elongation and Ductility Tests in Rail Sections under the Manufacturers' Standard Drop-Testing Machine, P. H. Dudley; Cupreo-Nickel Steel, G. H. Clamer; Report of Committee on Standard Specifications for Cement, George F. Swain, Mem. Am. Soc. M. E., chairman; Aluminates: Their Properties and Possibilities in Cement Manufacture, Henry S. Spackman, Mem. Am. Soc. M. E.; Tests on Reinforced Concrete Columns subjected to Repeated and Eccentric Loads, M. O. Withey; Report of Committee on Standard Specifications for Coal, J. A. Holmes, Mem. Am. Soc. M. E., chairman; Fuel Investigations, U. S. Geological Survey; Progress during the year ending June 30, 1910, J. A. Holmes, Mem. Am. Soc. M. E.; Report of Committee on Standard Specifications for Vitrified Clay and Cement Sewer Pipe, Rudolph Hering, Mem. Am. Soc. M. E., chairman; A Comparison of Magnetic Permeaters, Chas. W. Burrows.

On Wednesday evening, June 29, a session was held in honor of the memory of Dr. Charles B. Dudley, Mem. Am. Soc. M. E., late president of the society and of the International Association for Testing Materials. The various phases of Dr. Dudley's life and life-work were treated by Theodore N. Ely, Mem. Am. Soc. M. E., Prof. Edgar F. Smith, Prof. Henry M. Howe, Lieut.-Col. B. W. Dunn, W. H. Schwartz, and Robert W. Hunt, Mem. Am. Soc. M. E.

The following officers were elected: President, Prof. Henry M. Howe of New York; Secretary and Treasurer, Prof. Edgar Marburg; Vice-President, Robert W. Lesley; Member of Executive Committee, James Christie, Mem. Am. Soc. M. E.

OHIO ELECTRIC LIGHT ASSOCIATION

At the 16th annual convention of the Ohio Electric Light Association held from July 26-28 at Cedar Point, O., papers were presented on Turbine Troubles by Frank Brosius; Outline of an Equitable Power Rate, B. H. Gardner; Central Station Facts and Factors, J. R. Cravath; Motors for Single-Phase Circuits as They Are Today, Prof. F. C. Caldwell; Low-Pressure Turbines and their Operation, W. C. Anderson.

CANADIAN ELECTRICAL ASSOCIATION

The twentieth annual convention of the Canadian Electrical Association was held July 6-8, 1910, at Lake Rosseau, Ontario, Canada, with the Royal Muskoka Hotel as its headquarters.

Among the papers presented were: Protection of Service in Large Electric Systems, A. S. Loiseaux; Notes on Transmission Line Regulation, Paul M. Lincoln, Mem. Am. Soc. M. E.; Tungsten Street Lighting with Special Reference to 25-cycle Circuits, C. L. Stephens; The Diesel Oil Engine, F. A. Yerbury.

A number of special committee reports were presented, including those of the committees on standardization of line construction, grounding of transformer secondaries, installation, care and testing of meters, conservation of natural resources.

AMERICAN CHEMICAL SOCIETY

The American Chemical Society at its annual convention in San Francisco, Cal., from July 12-16, 1910, held a general session of its membership on July 13, followed by divisional sessions on the succeeding days. Among the papers presented before the division of agriculture and food chemistry was that on the Extent and Composition of the Incrustation on Filter Sands, by Edward Bartow and C. E. Millar. A symposium on smelter smoke was given before the division of industrial chemists and chemical engineers, including Neutralization and Filtration of Smelter Smoke, by W. C. Ebaugh; The Smoke Problem and the Community, by Charles Baskerville.

NATIONAL CONSERVATION CONGRESS

The second National Conservation Congress will be held at St. Paul, Minn., September 6-9, 1910. The objects of the Congress are (1) To provide for discussion of the resources of the United States as the foundation for the prosperity of the people; (2) To furnish definite information concerning the resources and their development, use and preservation; (3) To afford an agency through which the people of the country may frame policies and principles affecting the conservation and utilization of their resources to be put into effect by their representatives in state and federal government.

PERSONALS

Charles Whiting Baker served as a delegate from the United States appointed by the State Department at the International Congress of Mining, Metalurgy and Applied Mechanics at Düsseldorf, June 1910.

John C. Bertsch has been appointed a delegate by the United States to the Second International Congress of Refrigerating Industries at Vienna, to be held next October.

Prof. L. P. Breckenridge of the department of mechanical engineering at Sheffield Scientific School, Yale University, received the honorary degree of Doctor of Engineering at the commencement of the University of Illinois. Professor Breckenridge was formerly a member of the faculty at the latter university.

H. M. Byllesby has been elected a director of the Chicago, Milwaukee, Puget Sound R. R.

N. A. Carle has opened an office in the Central Building, Seattle, Wash., for practice as consulting and contracting engineer in mechanical, electrical and mining work.

Geo. W. Clancy, formerly general shop inspector of the New Haven System, Readville, Mass., has become president of the Globe Chemical Co., Boston, Mass.

Frank S. Clark has been transferred from the Cincinnati Traction Co. to the Ohio Electric Railway Co., as assistant engineer, with headquarters in Springfield, O.

W. L. R. Emmet received the degree of Doctor of Science from Union University at its recent commencement.

J. H. Fox, of Frazier & Fox, Cleveland, Ohio, has accepted an appointment as chief engineer of the Pittsburg Plate Glass Co., Pittsburg, Pa.

Howard D. Hess, formerly assistant professor of machine design at Cornell University, Ithaca, N. Y., has been made professor of machine design.

Thomas H. Mirkil, Jr., has resigned as general manager of the Southward Foundry & Machine Co., Philadelphia, Pa., to accept a similar position with the Poole Engineering and Machine Co., Baltimore, Md.

V. M. Palmer, chief engineer of the Selden Motor Vehicle Co., Rochester, N. Y., has resigned his position to accept a similar position with the Sheldon Axle Co., Wilkes Barre, Pa.

William E. Smith, formerly a draftsman with the Babcock & Wilcox Co., Barberton, O., now holds a similar position with the Browning Engineering Co., Cleveland, O.

Wm. S. Twining has resigned as chief engineer of the Philadelphia Rapid Transit Co., to become associated with Ford, Bacon & Davis, New York.

H. H. Westinghouse, has been elected president of Westinghouse, Church, Kerr & Co., New York.

On June 1, Columbia University conferred the degree of Doctor of Science on Sir William Henry White, Hon. Mem. Am. Soc. M. E.

CURRENT BOOKS

THE ELEMENTS OF REINFORCED CONCRETE BUILDING. By G. A. T. Middleton. *New York, Spon & Chamberlain, 1910.* Cloth, 8vo, 111 pp., illustrated. Price, $1.50.

Contents: Rectangular Beams with Supported Ends; Bending Moments—Resistance Moments—Designing from given data; Vertica; Reinforcements; T-and L-Beams with Supported Ends; Continuous Beams; Beams with Double Reinforcement; Floor Slabs; Foundations; Colnmns; Walls and Retaining Walls; Materials; Mixing and Laying the Concrete—Falsework, or Centering—Connections; Some Patent Systems.

METROPOLITAN WATER AND SEWERAGE BOARD, 9th Annual Report, 1909. *Boston, Wright & Potter Printing Co., 1910.* Cloth, 8vo, 272 pp., illustrations and maps.

Contents: Organization and Administration; Metropolitan Water District; Metropolitan Water Works—Construction; The Construction of the Metropolitan Water Works from 1895 to 1910; Water Works—Maintenance; Water Works—Financial Statement; Metropolitan Sewerage Works; Sewerage Works—Financial Statement; Consumption of Water; Electrolysis; Recommendation for Legislation; Future Work.

RAILROAD STRUCTURES AND ESTIMATES. By J. W. Orrock. 1st edition. *New York, John Wiley & Sons, 1909.* Cloth, 8vo, 270 pp., illustrated. Price, $3.

Contents: Track Material; Fences, Gates, Sign Posts, Road Crossings and Guards; Culverts; Bridges; Buildings; Water Stations; Shops; Specifications and Contracts; Estimating Notes.

PRINCIPLES OF REINFORCED CONCRETE CONSTRUCTION. By F. E. Turneaure and E. R. Maurer. 2d edition, revised and enlarged. *New York, John Wiley & Sons, 1909.* Cloth, 8vo, 429 pp., illustrated. Price, $3.50.

Contents: Introductory; Properties of the Material; General Theory; Tests of Beams and Columns; Working Stresses and General Construction Details; Formulas, Diagrams and Tables; Building Construction; Arches; Retaining Walls and Dams; Miscellaneous Structures; Re-inforced Concrete Chimneys.

ACCESSIONS TO THE LIBRARY

This list includes only accessions to the library of this Society, included in the Engineering Library. Lists of accessions to the libraries of the A. I. E. E. and A. I. M. E. can be secured request from Calvin W. Rice, Secretary, Am.Soc.M.E.

AMERICAN CERAMIC SOCIETY. Transactions. Vol. 1–2. *Columbus, O., 1900.* Gift of the society.

AMERICAN RAILWAY ASSOCIATION. Proceedings of special session held in New York City, January 27, 1910. *New York, 1910.* Gift of the association.

AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS. Transactions. Vol. 2, No. 2. *Madison, 1908.* Gift of the society.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Proceedings. Vol. 28, No. 1–4. *New York, 1906.*

ANNUAIRE DE LA JEUNESSE. 1909. By H. Vuibert. *Paris, 1909.* Gift of Société des Ingenieurs Civil de France.

CENTRAL RAILWAY CLUB. Proceedings. April 1894, September 1896, November 1901, January 1902, January and September 1906. *New York, 1894, 1896, 1901, 1902, 1906.*

CITY AND GUILDS OF LONDON INSTITUTE. Programme of the City and Guilds Central Technical College. June 1910. *London, 1910.* Gift of institute.

CLINKERS AND THE FUSING TEMPERATURE OF COAL ASH. By E. G. Bailey. *1910.*

COMMISSION PERMANENTE INTERNATIONALE D'AERONAUTIQUE. Procès verbaux et comptes rendus des travaux de la session extraordinaire, tenue à Bruxelles, Sept. 12-15, 1907. *Paris, Dunod et Pinat, 1908.*

ELECTRIC TRACTION ON CITY AND SUBURBAN RAILWAYS. By H. M. Hobart. Gift of C. W. Rice.

ELEMENTS OF REINFORCED CONCRETE BUILDING. By G. A. T. Middleton. *New York, Spon & Chamberlain, 1910.*

HOW TO SAMPLE COAL AND COKE. By E. G. Bailey. *1910.*

ILLINOIS SOCIETY OF ENGINEERS AND SURVEYORS. Twenty-fifth Annual Report. 1910. *Chicago, 1910.* Gift of the society.

LELAND STANFORD JUNIOR UNIVERSITY. Register 1909-1910. *San Francisco.* Gift of the university.

LOW GRADE PORPHYRY COPPER MINES. *1910.*

MASSACHUSETTS WATER COMMISSIONERS. Thirty-sixth Annual Report. 1909. *Springfield, 1910.* Gift of the Board.

METALLOGRAPHIE. By W. Guertler. Vol. 1, Pt. 3. *Gebrüder Borntraeger, Berlin, 1910.*

METROPOLITAN WATER AND SEWERAGE BOARD. Ninth Annual Report. 1910. *Boston, 1910.* Gift of the board.

MILWAUKEE SMOKE INSPECTOR. *Annual Report.* 1909. *Milwaukee, 1909.*

Municipal Engineers of the City of New York. List of Members. 1909. *New York, 1910.* Gift of Municipal Engineers.

New England Railroad Club. Proceedings. Jan. 11, Feb. 8, March 8, April 12, May 10, Oct. 11, Nov. 8, Dec. 13, 1898; Jan. 10, Oct. 10, 1899; Jan. 9, Feb. 13, March 13, April 10, May 8, Oct. 9, Nov. 13, Dec. 11, 1900; Jan. 14, March 12, Nov. 11, 1902; March 10, Nov. 10, 1903; Jan. 12, Feb. 9, March 8, April 12, May 10, 1904. *Boston, 1898-1900, 1902-1904.*

New York City Board of Education. Annual Financial and Statistical Report of the Transactions of the Board. 1906-1908. *New York, 1909.* Gift of the Board of Education.

New York Railroad Club. Proceedings. Feb. 15, 1894, and Jan. 17 and March 21, 1895. *New York, 1894-1895.*

Pennsylvania Water Supply Commission. Annual Report. 1908. *Harrisburg, 1910.* Gift of the commission.

Principles of Reinforced Concrete Construction. By F. E. Turneaure and E. R. Maurer. *New York, J. Wiley & Sons, 1909.*

Quatrième Congrès International d'Aeronautique, Nancy, Sept. 18-23, 1909. Procès Verbaux, Rapports and Mémoires. *Paris, 1909.*

Railroad Herald. Vol. 12, 1907-1908. *Atlanta, 1907-1908.*

Railway Statistics of the United States of America. 1909. *Chicago, 1910.* Gift of Slason Thompson.

Railroad Structures and Estimates. By J. W. Orrock. *New York, J. Wiley & Sons, 1909.*

Reinforced Concrete Pocket Book. By L. J. Mensch. *San Francisco, 1909.* Gift of author.

Richmond Railroad Club. Proceedings. Vol. 1, No. 1-7; Vol. 2, No. 3-7 and 9; Vol. 3, No. 1-9. *Richmond, 1902-1904.*

Southern and Southwestern Railway Club. Constitution and Proceedings. Nov. 16, 1893; Jan. 18, April 19, Aug. 16, Nov. 15, 1894; Jan. 17, April 18, Aug. 15, 1895; Jan. 16, April 16, Aug. 20, Nov. 19, 1896; Jan. 21, April 8, 1897; Vol. 5, No. 1-8, 1900-1901. *Atlanta, 1893-1897, 1900, 1901.*

Standard Specifications for Creosoted Wood Block Pavement. Gift of J. W. Howard.

Steam Turbines. By Wilhelm Gentsch. Translated from the German by A. R. Liddell. *New York, Longmans, Green & Co., 1906.*

Traveling Engineers' Association. Proceedings of Annual Convention. 1907, 1908. *Buffalo, 1907-1908.*

EXCHANGES

American Electrochemical Society. Hand Book of the Pittsburg Meeting May 4-7, 1910. *1910.*

American Society of Civil Engineers. Transactions. Vol. 67, 1910. *New York, 1910.*

Block Signals on the Railroads of the United States. Jan. 1, 1910. *Washington, 1910.*

Brooklyn Engineers Club. Proceedings. 1909. *Brooklyn, 1910.*

Canadian Society of Civil Engineers. Charter, By-Laws and List of Members. 1910. *Montreal, 1910.*

—Report of Annual Meeting. Vol. 24, 1910. *Montreal, 1910.*

New England Water Works Association. Constitution and List of Members. May 1910. *Boston, 1910.*

Society of Naval Architects and Marine Engineers. Transactions. Vol. 17, 1909. *New York, 1909.*

Technograph. Vol. 24, 1910. *Champaign, Univ. of Illinois, 1910.*

TRADE PUBLICATIONS

American Blower Co., *Detroit, Mich.* Bull. No. 267. Detroit steam traps and return trap system, 32 pp.; Bull. No. 273. A B C Hot-Air Heater, 18 pp.

American Electrical Works, *Phillipsdale, R. I.* Price list of wires and cables for electric work, 10 pp.

Contractors Supply and Equipment Co., *Denver, Colo.* Catalogue of contractors' supplies, construction machinery, and repair castings for machines, 44 pp.

Hans Renold, Ltd., *Manchester, Eng.* Driving chains for power transmission, 130 pp.

Hess-Bright Mfg. Co., *Philadelphia, Pa.* Ball bearings and their correct use, 1 p.

Internationale Rotations—Maschinen Gesellschaft, *Berlin, Germany.* Universal rotary engines, 101 pp.

Kieley & Mueller, *New York City.* 1910 catalogue of steam, watei, and air specialties, 100 pp.

Link-Belt Co., *Philadelphia, Pa.* Conveying machinery for coal mines, 42 pp.

David Lupton's Sons Co., *Philadelphia, Pa.* Steel sashes and skylights, hollow metal windows, continuous sashes, etc., 52 pp.

National Electric Lamp Assoc., *Cleveland, O.* Bull. No. 11. Operation, manufacture and efficiency of Mazda street service lamps, 11 pp.

Niederrheinisches Eisenwerk, *Dülken, Germany.* Suction cleaning apparatus, 7 pp.

Penton Publ. Co., *Cleveland, O.* Penton's List, May 1910, 8 pp.

Wm. Powell Co., *Cincinnati, O.* Catalogue No. 9. Brass steam and water supplies, valves, gauges, oiling devices, lubricators, etc., 281 pp.

Providence Engineering Works., *Providence, R. I.* Rice and Sargent Corliss engines, 55 pp.

Joseph T. Ryerson & Son, *Chicago, Ill.* Monthly stock list of machinery, iron and steel supplies, May and June 1910, 144 pp. each.

Sprague Electric Co., *New York City.* Catalogue No. 321. Electric fans, 35 pp.

Underfeed Stoker Co. of America, *Chicago, Ill.* Publicity Magazine, May and June, 1910, 15 pp. each.

Villinger Mfg. Co., *Williamsport, Pa.* 14 in. friction drill with quick change speed, 3 pp.

W. Douglas Wooley, *St. Louis, Mo.* C.—C. non-gap lightning arresters, 4 pp.

UNITED ENGINEERING SOCIETY

Annalen der Hydrographie und Maritimen Meteorologie. Year 38-date. *Berlin, 1910-date.*

Cyclopedia of Automobile Engineering. Vol. 1-4. *Chicago, 1910.*

Journal für Gasbeleuchtung. General Register zum jahrgang 32-46 (1889-1903). *München, 1905.*

McNeill, Bedford, Code, 1908 edition. *London, 1908.* Tables for McNeill's Code, 1908 edition.

Nevada State Controller. Annual Report. 1905-1909. *Carson City, 1906-1910.* Gift of Nevada State Controller.

Ohio Railroad Commission. Fourth Report. *Springfield, 1910.* Gift of the commission.

Poor's Manual of Industrials, 1910. *New York, Poor's Railroad Manual Co., 1910.*

Practical Instructions Relating to the Construction and Use of the Steam Engine Indicator. *Boston, Crosby Steam Gage & Valve Company, 1910.* Gift of Alfred B. Carhart.

Society for the Promotion of Engineering Education. Proceedings. Vol. 17. *Ithaca, 1910.*

GIFT OF THE AMERICAN GAS INSTITUTE

American Gas Light Journal. Vol. 56-67. *New York, 1892-1897.*

Association of Gas Engineers and Managers, United Kingdom. Report of Proceedings. 1887-1897. *London, 1888-1898.*

British Associations of Gas Managers. Report of Proceedings. 1876-1879. (Title changed to Gas Institute in 1881.)

Congrès International de l'Industrie de Gaz. Compte rendu des Travaux. Publiè par les Soins de la Société Technique de l'Industrie de Gazen France. 15th-28th, 30th-36th Congress. Paris, 1888-1901, 1903-1909.

——Assemblée Générale Rapports Annexes. *Paris, 1900.*

Deutscher Verein von Gas und Wasserfachmännern. Verhandlungen. 1903-1907. *München, 1903-1907.*

Gas Institute. Transactions. 1884, 1885. *London, 1884-85.*
(Early title to 1881, British Association of Gas Managers.)

Incorporated Gas Institute. Transactions. 1896, 1897, 1899, 1900. *London, 1896-97, 1899-1900.*
(Merged in 1902 to form Institution of Gas Engineers.)

Incorporated Institution of Gas Engineers. Transactions. Vol. 1-6, 8-12. London, 1892-1903.
(Merged with Gas Institute in 1902 to form Institution of Gas Engineers.)

Institution of Gas Engineers. Transactions. 1903-1908. *London, 1903-1908.*

Progressive Age. Vol. 9-14 (6 vol. in three). *New York, 1891 1896.*

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 12th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

039 Young technical graduate in mechanical engineering for designing department of steam engine manufacturers. More especially on the Corliss type. Man with one to three years experience preferred. Excellent chance of advancement if aptitude and initiative are shown.

040 Large eastern manufacturing company wants a mechanical engineering graduate of not less than five years' experience in similar work to act as assistant engineer in the design, estimating and construction of electric power generating plants and general construction engineering. Salary, about $2000, depending on the man.

041 Civil engineering graduate of not less than five years experience to act as assistant engineer in the design of electric power plants and general construction engineering, for large eastern manufacturing company. Should have had experience in foundation work, structural steel, reinforced concrete and general building design and estimating therefor. Must be willing to do work partly of a mechanical or electrical engineering nature, according to his ability and as occasion requires. Salary, about $1500 depending on the man.

042 Master mechanic wanted for stationery manufacturing plant in Massachusetts. Man 30 to 35 years of age with technical education, preferred. Would have charge of power, construction, repairs and general oversight of buildings. Salary, $1500 per year.

MEN AVAILABLE

95 Member, 40 years of age, graduate, chief engineer, originator, designer of gas engines (any size), gas producers (any fuel), gas furnaces (any purpose). American citizen, engineer of construction in large European steelworks, desires to return into suitable position; perfect in English, French and German.

96 Mechanical and structural engineer, fifteen years experience designing machinery, furnace, rolling mill plants and buildings. Technical education. Desires position as chief draftsman or chief engineer.

97 Junior member, graduate Cornell, several years experience technical journalism, experimental and efficiency engineering, desires change. Familiar with open hearth and rolling mill work and general machine shop practice. Desires position in which ability and energy will be recognized and will lead to high-class executive position.

98 Technical and manual training school graduate, age 34, good experience in drafting, estimating, practical machine shop work and testing, desires position preferably in Pennsylvania.

99 Seven years varied engineering experience and six years in selling end. Would consider position where knowledge of machinery and mill supply trade of the United States and Canada is essential. Experience in correspondence and proper design of selling contracts.

100 Cost reduction and production expert; results of last two years work giving an annual net saving of $50,000 open to proposition from reliable parties. Competent and experienced executive.

101 Engineer executive desires to correspond with concern offering field for general engineering and assistant in general office. Salary, minimum $2400.

102 Mechanical engineer, eleven years practical experience, six years in automobile and commercial vehicle business desires high grade shop or executive position. Competent to manage small shop, or would connect with large firm as assistant superintendent or assistant manager. Experience covers drafting room shop, office, advertising, publicity, and executive duties. Salary $3000.

103 Eastern member, experience as civil and mechanical engineer, designing construction, selling, installation and operation departments of modern power equipment and manufacturing plants; wide personal acquaintance United States, Canada, Great Britain and the continent; successful in dealing with U. S. and foreign government engineer departments, municipal and other public works; familiar with modern office, shop organization and costs; drafting specifications and contracts; good correspondent and executive; active, energetic and resourceful.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

ALSBERG, Julius (Junior, 1905), Asst. to John Bogart, Const. Engr., 141 Broadway, and 56 W. 95th St., New York, N. Y.

BASFORD, Geo. M. (1889: 1891), Manager, 1905-1909; Asst. to Pres., Am. Loco. Co., 30 Church St., New York, and 134 Primrose Ave., Mt. Vernon, N. Y.

BAXTER, Burke Morgan (Junior, 1908), 1799 Wilton Rd., Cleveland, and *for mail*, Middletown, O.

BENCH, Alfred Rittscher (Junior, 1907), W. H. Zimmerman Co., 903 First Natl. Bank Bldg., Chicago, Ill.

BERTSCH, John Charles (1901), Cons. Engr., 611 Lamar St., Fort Worth, Texas.

BLAKE, Edwin Mortimer (1907), Rm. 1406, 1 Liberty St., New York, N. Y.

BORNHOLT, Oscar Charles (Junior, 1904), Mech. Engr., Ford Motor Co., Piquette Ave. and Beaubien St., Detroit, Mich.

CAMERON, Barton H. (1903), Pres., Cameron Stove Co., and *for mail*, 116 N. Morris St., Richmond, Va.

CHAMBERLAIN, Harry M. (1907), N. Y. C. & H. R. R. R., and *for mail*, Park Chambers, Springfield, Mass.

CLANCY, Geo. W. (Associate, 1909), Pres., Globe Chemical Co., 68 Devonshire St., Boston, and *for mail*, 172 Harvard St., Brookline, Mass.

CLARK, Frank S. (Associate, 1909), Asst. Engr., Ohio Elec. Ry. Co., Springfield, and *for mail*, 132 Bellevue Apts., Dayton, O.

DAVIS, George H. (Junior, 1907), Designer, Inspr., Pub. Wks. Office, Brooklyn Navy Yard, and *for mail*, 608 E. 26th St., Brooklyn, N. Y.

DILLARD, James B. (1907; Associate, 1909), Capt. Ordnance Dept., U. S. A., War Dept., Ft. Adams, Newport, R. I.

DIXON, Charles F. (Junior, 1903), Engrg. Dept., New England Engrg. Co., 50 Church St., New York, N. Y.

DOUD, Arthur T. (Junior, 1907), care Genl. Delivery, Jackson, Mich.

FEICHT, Edward R. (Junior, 1907), Ch. Engr., Sacramento Valley Sugar Co., Hamilton City, Cal.

FIRTH, William Edgar (1893), Mech. Engr., Midvale Steel Co., Box 1606, and 400 W. Chelten Ave., Germantown, Philadelphia Pa.

FORGY, J. Edmonds (Junior, 1906), Charles Warner Co., Du Pont Bldg., Wilmington, Del.

FOSTER, Horatio A. (1895), 332 Oliver Bldg., Pittsburg, Pa.

FOX, John Herbert (1904), Ch. Engr., Pittsburg Plate Glass Co., Frick Bldg., Pittsburg, Pa.

GARLAND, Claude Mallory (Associate, 1906), Mech. Engr., Camden Iron Wks., Camden, and *for mail*, 102 Linden Ave., Collingswood, N. J.

GREEN, John Stevenson (Junior, 1909), 168 Gay St., Manayunk, Philadelphia, Pa.

HALL, Frederick Bellows (1905), Mech. Engr., W. E. Baker & Co., 105 W. 40th St., and 40 Morningside Ave., New York, N. Y.

HANSON, Augustus (1886), 1085 14th St., San Francisco, Cal.

HERBERT, Jack Stanley (1908), Pres., Herbert Engrg. Co., Fleming Bldg., Easton, Pa.

HIGDON, John C. (Associate, 1901), Mech. Engr., Atty.-at-Law and Pat. Solicitor, 605 Missouri Trust Bldg., St. Louis, Mo.

HILLYER, George, Jr., (1898; Associate , 1904), Mgr., Broad River Granite Co., and *for mail*, 5 Crew St., Atlanta, Ga.

IDELL, Percy C. (1901; 1909), Mech. Engr., Sales Dept., Babcock & Wilcox Co., 85 Liberty St., New York, and *for mail*, 157 83rd St., Brooklyn, N. Y.

JACOBI, Albert W. (1885), 286 S. Sixth St., Newark, N. J.

JUNGHANS, Edward K. (1908), care Hendricks & Class, 30 Church St., New York, N. Y.

KEELY, Royal R. (1901; 1907), 360 W. 123rd St., New York, N. Y.

KING, Roy S. (Junior, 1904), Gary, Ind.

LAFORE, John Armand (1904) Sales Mgr., D'Olier Engrg. Co., 121 S. 11th St., Philadelphia, Pa.

LAND, Frank (1900), Secy. and Treas., Land-Wharton Co., 912 Pa. Bldg., Philadelphia, and *for mail*, P. O. Box 145, Berkeley Rd., Merion Sta., Pa.

LATON, Thomas J. (Junior, 1908), Instr. in Drawing and Mech. Engrg., N. H. College, Durham, and *for mail*, Box 14, Madbury, N. H.

McCOLL, J. R. (1903), Member of Firm, Ammerman, McColl & Anderson, 1330-1332 Penobscot Bldg., and 545 John R. St., Detroit, Mich.

McMULLEN, V. E. (Associate, 1907), Genl. Foreman, Gas Eng. Dept., Fairbanks, Morse Mfg. Co., and *for mail*, 1251 Josephine Ave., Beloit, Wis.

MEYER, C. Louis (Junior, 1909), care of Engrg. Dept., Trussed Concrete Steel Co., Detroit, Mich.

NICKEL, Franz F. (1899), 27 Winans St., East Orange, N. J.

PALMER, Virgil Maro (Junior, 1905), Ch. Engr., Sheldon Axle Co., Wilkes-Barre, Pa.

PARSONS, Willard P. (1884), 30 Saratoga Ave., Cohoes, N. Y.

PEDDLE, John Bailey (1909), Prof. Mch. Design, Rose Poly. Inst., Terre Haute, Ind., and *for mail*, R. R. 3, Boyne City, Mich.

PEEK, George Meredith (1892;1900), 562 Bartmer Ave., St. Louis, Mo.

PHARR, Eugene A. (1908), Sugar Planter and Mfr., Morgan City, La.

RIDDLE, Howard Sterling (1905), 433 King Ave., Columbus, O.

SCHLATTER, Rudolf (1901), care Sulzer Bros., Pahnhof, Winterthur, Switzerland.

SCHWARTZ, Carl (1906), Engr., Power Stations, N. Y. C. &. H. R. R. R. Co., Grand Central Sta., Rm. 1231, New York, and 9 Siwanoy Ave., New Rochelle, N. Y.

SHRIVER, Harry T. (Junior, 1893), Prop., T. Shriver & Co., Harrison, and *for mail*, Llewellyn Park, West Orange, N. J.

SMITH, Augustus (1902), Constr., Ft. W. Fifth St., Bayonne, N. J.

SMITH, William E. (Junior, 1908), Draftsman, Browning Engrg. Co., and *for mail* 11212 Ashbury Ave., Cleveland, O.

STEVENS, Robt. H. (Junior, 1903), Stevens Bros., Engrs. and Contrs., 149 Broadway, New York, N. Y.

STREETER, Robert Leroy (Associate, 1907), Asst. Prof. Mech. Engrg., Rensselaer Poly. Inst., Troy, N. Y.

SYMINGTON, E. Harrison (Associate, 1903), T. H. Symington Co., 616 Ry. Exch., Chicago, Ill.

VANDEMOER, John (Associate, 1904), Cia Metalurgica Nacional, Matehuala, S. L. P., Mexico.

WELLS, J. Barnard (Junior, 1909), Draftsman, A. T. & S. F. Ry., San Bernardino, and *for mail*, 1544 Pleasant Ave., Los Angeles, Cal.

WETMORE, Charles P. (1901), Pres., Am. Adding Mch. Co., and *for mail* Rm. 39, 427 Randolph St., Chicago, Ill.

WHITE, Maunsel (1882), Life Member; Cons. Engr. and Steel Met., P. O. Box 741, New Orleans, La.

WHYTE, Frederic M. (1902), Vice-President, 1908–1910: Genl. Mgr., New York Air Brake Co., Watertown, and *for mail*, 14 Benedict Ave., Tarrytown, N. Y.

WILLIAMSON, Leroy A. (Associate, 1902), Pres., L. A. Williamson Co., 79 Milk St., Boston, Mass.

WILSON, Clarence C. (Junior, 1900), 22 First St., San Francisco, Cal.

WOOD, Erwin E. (1900), Life Member; Genl. Mgr., Grant & Wood Mfg. Co., Chelsea, Mich.

WRIGHT, Reginald A. (1907), Ch. Draftsman, Phila. &. Reading Coal & Iron Co., and *for mail*, 1959 W. Market St., Pottsville, Pa.

NEW MEMBERS

BAILEY, Alex. D. (Junior, 1910), Asst. to Ch. Engr., Commonwealth Edison Co., and *for mail*, 1865 S. Avers Ave., Chicago, Ill.

BANCROFT, George Arthur (Junior, 1910), Asst. to Mech. Engr., Oil Tractor Dept., M. Rumely Co., and *for mail*, 708 Harrison St., La Porte, Ind.

BARNES, Arthur F. (Junior, 1910), 119 Webster St., Worcester, Mass.

BEDELL, E. H. (Junior, 1910), 479 Ridge St., Newark, N. J.

BROWN, Walter Ellsworth (Junior, 1910), Hotel Stirling, Easton, Pa.

BURGESS, A. Bradley (Junior, 1910), Estimating Engr., Standard Plunger Elevator Co., 115 Broadway, New York, N. Y., and *for mail*, 48 N. 18th St., East Orange, N. J.

CLARK, William Van Alan (Junior, 1910), Draftsman and Inspr., Constr. Wk., Matawan, N. J.

COOLEY, Hugh Nelson (Associate, 1910), Rep., Nordberg Mfg. Co., in Southwestern U. S. and Mexico, and *for mail*, 3414 Cedar St., Milwaukee, Wis.

CORREA, William Howard (Junior, 1910), Asst. M. M., Standard Oil Co., Pratt Wks., Brooklyn, and *for mail*, 422 W. 20th St., New York, N. Y.

DAVIS, William J., Jr. (1910), Pacific Coast Engr., Genl. Elec. Co., Union Trust Bldg., San Francisco, Cal., also Ch. Engr., Mexican Northern Power Co., Montreal, Can.

DORWARD, David, Jr. (1910), Ch. Engr., Union Oil Co. of California, 235 Mills Bldg., San Francisco, Cal.

FENN, Robert Wilson (1910), Mgr. Mfg. Dept., Union Oil Co. of Cal., Mills Bldg., San Francisco, Cal.

FOLEY, Walter Joseph (Junior, 1910), Estimator, Risdon Iron Wks., and *for mail*, 115 Frederick St., San Francisco, Cal.

GERNANDT, Waldo George (Junior, 1910), Ch. Draftsman, Rapid Motor Vehicle Co., and *for mail*, Box 497, Pontiac, Mich.

GRANT, Charles C. (Junior, 1910), Goodyear Tire & Rubber Co., and *for mail*: 1012 Sydney St., Akron, O.

HAMMOND, John Hays (1910), Cons. Engr., 71 Broadway, New York, N. Y.

HEIDELBERG, Frederick Martin (Junior, 1910), Asst. Labor Foreman, Am. Constr. Co., and *for mail*, 1417 Pease Ave., Houston, Tex.

HOOD, Warren Blake (Junior, 1910), Piece-Work Inspr., Canadian Pacific Ry., and *for mail*, 725 Dorchester St. W., Montreal, P. Q., Canada.

McKIBBEN, H. B. (Junior, 1910), Constr. Engr., Olathe, Colo.

MERRELL, Irving Seaward (1910), V. P. and Mech. Engr., Merrell-Soule Co., and *for mail*, 524 W. Onondaga St., Syracuse, N. Y.

MORRIS, Thomas Bray (Junior, 1910), Kilbourne & Jacobs Mfg. Co., Columbus, and *for mail*, 2846 Harrison Ave., Cincinnati, O.

OATLEY, Henry Biglow (1910), Asst. Engr., Genl. Drawing Room, Am. Loco. Co., Schenectady, N. Y.

NEIDHARDT, J. Wm. (1910), Asst. to Genl. Mgr., Detrick & Harvey Mch. Co., and *for mail*, 1807 W. Baltimore St., Baltimore, Md.

PAULSMEIER, Albert Carl (1910), Ch. Engr. and Supt., Byron Jackson Iron Wks., San Francisco, and *for mail*, 1530 Union St., Alameda, Cal.

PEPER, John Henry, Jr. (Junior, 1910), Asst. to D. S. Bushnell, Rm. 1107, 26 Broadway, New York, N. Y.

ROWLEY, Ridgway Lloyd (Junior, 1910), Inspc. Engr., Bd. of Fire Underwriters of the Pacific, 1414 Merchants Exch., San Francisco, Cal.

SCHOENIJAHN, Robert P. (Junior, 1910), Mech. Engr., L. B. Marks & J. E. Woodwell, Cons. Engr., and *for mail*, 1124 Eastern Parkway, Brooklyn, N. Y.

SNOW, Norman Leslie (Junior, 1910), Asst. Sales Mgr., Terry Steam Turbine Co., 90 West St., New York, N. Y., and *for mail*, 1342 Watchung Ave., Plainfield, N. J.

SPRAU, William C. (Junior, 1910), Mech. Engr., Arnold Co., and *for mail*, 1445 Melville Pl., Chicago, Ill.

TAYLOR, Harvey Birchard (Junior, 1910), Asst. Hydr. Engr., I. P. Morris Co., Beach and Ball Sts., Philadelphia, Pa.

THOMA, Charles, Jr. (Junior, 1910), Supt., Die Dept., E. W. Bliss Co., Brooklyn, N. Y., and *for mail*, 15 Eighth St., Carlstadt, N. J.

THOMA, Walter (Junior, 1910), Ch. Mech. Inspr., E. W. Bliss Co., Brooklyn, N. Y., and *for mail*, 15 Eighth St., Carlstadt, N. J.

YEOMANS, Lucien I. (1910), 416 E. 48th Pl., Chicago, Ill.

PROMOTIONS

BATTON, Percy H. (1901; 1910), Genl. Supt., Featherstone Fdy. & Mch. Co., and *for mail*, 21 E. Walton Pl., Chicago, Ill.

YOUNG, John Mason (1902; 1910), Dean of Engrg., College of Hawaii, Honolulu, Hawaii.

DEATHS

BETTENDORF, William P., June 3, 1910.

CRANE, William Edward, May 22, 1910.

SNOW, William W., April 26, 1910.

GAS POWER SECTION

CHANGES OF ADDRESS

FOX, John Herbert (1908), Mem. Am.Soc.M.E.
HILLEBRAND, Herman (Affiliate, 1909), 638 W. Broadway, Bethlehem, Pa.

NEW MEMBERS

BUNNELL, Sterling Haight (1910), Mem.Am.Soc.M.E.
FORSTALL, Alfred E. (1910), Mem.Am.Soc.M.E.

STUDENT BRANCHES

CHANGES OF ADDRESS

ABBISS, Reuben D. (Student, 1910), 111 Mills Ave., Braddock, Pa.
ALTEKRUSE, I. B. (Student, 1909), 808 Mulberry Ave., Muscatine, Ia.
BONNELL, W. W. (Student, 1910), 435 Franklin St., Wilkinsburg, Pa.
BRENDLIN, Wm. F. (Student, 1909), Ft. W. 57th St., New York.
CANADAY, M. S. (Student, 1909), 752 Adams St., Gary, Ind.
CLOCK, F. A. (Student, 1909,) Clockville N. Y.
COLE R. F. (Student, 1910), 16 Pleasant St., South Portland, Me.
GLICK, G. A. (Student, 1910), 110 Youngs Ave., Joliet, Ill.
HERRMANN, George A. (Student, 1909), 411 E. 40th St., Chicago, Ill.
HOMS, J. M. (Student, 1910), care Emerson-Brantingham Co., Rockford, Ill.
JACOBS, Guy W. (Student, 1910), 11 W. King St., York, Pa.
KONSTANKEWICZ, M. J. (Student, 1910), 36 Adam St., Gary, Ind.
MALONE, C. J. (Student, 1910), 173 W. Second St., Chillicothe, O.
MARSH, Karl (Student, 1910), Suite 48, The Lincoln, Youngstown, O.
MATTHAI, A. D. (Student, 1910), Sta. E., Baltimore Co., Md.
MONESTEL, Alberto A. (Student, 1910), 514 Fifth St., Brooklyn, N. Y.
MONTGOMERY, Stafford (Student, 1910), 417 Second Ave., Rome, Ga.
MORGAN, Henry (Student, 1910), 809 N. Grand Ave., St. Louis, Mo.
PARMELY, J. C. (Student, 1909), Y.M.C.A. Bldg., Kewanee, Ill.
PEARSALL, A. C. (Student, 1910), 1720 Arlington Ave., Des Moines, Ia.
PINKHAM, C. J. (Student, 1910), R.F.D. 5, Farmington, Me.
PLANK, Wm. Jay (Student, 1909), 1014 S. Main St., Wichita, Kan.
REINICKER, Norman G. (Student, 1909), Harford and Mayfield Aves., Baltimore, Md.
REYNOLDS, H. B. (Student, 1909), Wyoming, Del.
RICHARDSON, Lawrence, Jr. (Student, 1909), 413-15th St., Altoona, Pa.
SCALES, Eugene M. (Student, 1910), Guilford, Me.
SHULTS, L. J. (Student, 1909), 1847 S. Sawyer Ave., Chicago, Ill.
SPONSEL, J. G. (Student, 1909), 1429 E. 61st Pl., Chicago, Ill.
SWIGGETT, C. A. (Student, 1909), 304 W. Madison St., Iola, Kan.
WEDDELL, George C. (Student, 1910), 11 W. King St., York, Pa.
WOOD, Stanley V. (Student, 1909), 334 S. Franklin St., Wilkes-Barre, Pa.
YODER, Jacob H. (Student, 1910), 21 Chestnut St., Sharon, Pa.

NEW MEMBERS

PENNSYLVANIA STATE COLLEGE

MOLLISON, Wm. R. (Student, 1910), Scottdale, Pa.

UNIVERSITY OF ILLINOIS

BERGERT, H. A. (Student, 1910), care Mahoning Valley Wks., Youngstown, O.

HODGSON, J. H. (Student, 1910), 1919 Third Ave., Moline, Ill.

UNIVERSITY OF NEBRASKA

STANCLIFF, A. D. (Student, 1910), Pecos, Tex.

DEATHS

HASKELL, W. M., June 25, 1910.

COMING MEETINGS

AUGUST—SEPTEMBER

Advance notices of annual and semi-annual meetings of engineering societies are regularly published under this heading and secretaries or members of societies whose meetings are of interest to engineers are invited to send such notices for publication. They should be in the editor's hands by the 15th of the month preceding the meeting. When the titles of papers read at monthly meetings are furnished they will also be published.

AMERICAN MINING CONGRESS
September 26-October 1, annual convention, Los Angeles, Cal. Managing director, Sidney Norman.

AMERICAN SOCIETY OF CIVIL ENGINEERS
September 7, 220 W. 57th St., New York, 8.30 p.m. Paper: Remedies for Landslides and Slips on the Kanawha and Michigan Railway, R. P. Black. Secy., C. W. Hunt.

ASSOCIATION OF EDISON ILLUMINATING COMPANIES
September 6-9, annual meeting, Hotel Frontenac, Thousand Islands, Can. Secy., N. T. Wilcox, Lowell, Mass.

THE COLORADO ELECTRIC LIGHT, POWER AND RAILWAY ASSOCIATION
September 21-23, annual convention, Glenwood Springs. Secy., F. D. Monis, 323 Hagerman Bldg., Colorado Springs, Col.

INTERNATIONAL ACETYLENE ASSOCIATION
August 3-5, annual meeting, Congress Hotel Annex, Chicago, Ill. Secy., A. Cressy Morrison, 157 Michigan Ave.

INTERNATIONAL CONGRESS OF HIGHER TECHNICAL EDUCATION
September 9-11, Brussels, Belgium. Commissioner, Elmer Ellsworth Brown. Bureau of Education, Department of Interior, Washington, D. C.

INTERNATIONAL HUNTING CONGRESS
September 5-7, Vienna, Austria. Secy., C. Kunsky, Wiesingerstrasse 8.

INTERNATIONAL RAILROAD BLACKSMITHS ASSOCIATION
August 17-19, annual convention, Detroit, Mich. Secy., A. L. Woodworth, Lima, O.

NATIONAL ASSOCIATION OF GERMAN-AMERICAN TECHNOLOGISTS
September 1-5, Newark, N. J. Secy., B. A. von Bergen, 842 Broad St.

NATIONAL ASSOCIATION OF MASTER SHEET METAL WORKERS
August 10-13, Lulu Temple, Broad and Spring Garden Sts., Philadelphia, Pa. Secy., Otto Goebel, 523 Columbus Ave., Syracuse, N. Y.

NATIONAL ASSOCIATION OF STATIONARY ENGINEERS
September Convention, Rochester, N. Y.

NATIONAL CONSERVATION CONGRESS
September 6-9, St. Paul, Minn. Secy., Thomas R. Shipp, Colorado Bldg., Washington, D. C.

NEW ENGLAND WATERWORKS ASSOCIATION
September 21-23, annual convention, Rochester, N. Y. Secy., Willard Kent Narragansett Pier, R. I.

PACIFIC COAST GAS ASSOCIATION
September 20-22, annual meeting, Los Angeles, Cal. Secy., John A. Britton, 925 Franklin St., San Francisco.

ROADMASTERS AND MAINTENANCE OF WAY ASSOCIATION
September 13-16, Chicago. Secy., W. E. Emery, West Chicago.

THE ROYAL ARCHITECTURAL INSTITUTE OF CANADA
August 24-27, annual meeting, Winnipeg, Man. Hon. Secy., Alcide Chausse, 5 Beaver Hall Square, Montreal.

TRAVELING ENGINEERS ASSOCIATION
August 16-19, annual convention, Clifton Hotel, Niagara Falls, Canada. Secy., W. O. Thompson, care of N. Y. C. Car Shops, East Buffalo, N. Y.

UNION OF CANADIAN MUNICIPALITIES
August 31-September 2, annual convention, Toronto, Ont. Secy., W. D. Lighthall, K. C., Westmount, Que.

MEETINGS IN THE ENGINEERING SOCIETIES BUILDING

Date	Society	Secretary	Time
June			p.m.
1	Blue Room Engineering Society	W. D. Sprague	8.00
2	Western Union Electrical Society	H. C. Northen	7.00
7	Wireless Institute	S. L. Williams	7.30
8	Illuminating Engineering Society	P. S. Millar	8.00
9	Western Union Electrical Society	H. C. Northen	7.00
16	New York Railroad Club	H. D. Vought	8.15
16	Western Union Electrical Society	H. C. Northen	7.00
23	Western Union Electrical Society	H. C. Northen	7.00
28	Municipal Engineers of New York	C. D. Pollock	8.15
28	Western Union Electrical Society	H. C. Northen	7.00

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Terms expire at Annual Meeting of 1910

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Terms expire at Annual Meeting of 1911

PAST-PRESIDENTS

Members of the Council for 1910

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Frederick W. Taylor.................................... Philadelphia, Pa.
F. R. Hutton.................................... New York
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MANAGERS

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Terms expire at Annual Meeting of 1910

H. L. Gantt.................................... New York
I. E. Moultrop.................................... Boston, Mass.
W. J. Sando.................................... Milwaukee, Wis.

Terms expire at Annual Meeting of 1911

J. Sellers Bancroft.................................... Philadelphia, Pa
James Hartness.................................... Springfield, Vt.
H. G. Reist.................................... Schenectady, N. Y.

Terms expire at Annual Meeting of 1912

TREASURER

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CHAIRMAN OF THE FINANCE COMMITTEE

Arthur M. Waitt.................................... New York

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Calvin W. Rice.................................... 29 West 39th Street, New York

EXECUTIVE COMMITTEE OF THE COUNCIL

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FINANCE

Arthur M. Waitt (5), *Chairman*
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HOUSE

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Bernard V. Swenson (2)
Edward Van Winkle (4)
H. R. Cobleigh (5)

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Ambrose Swasey (1)
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Alfred Noble (5)

MEETINGS

Willis E. Hall (5), *Chairman*
L. R. Pomeroy (2)
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H. de B. Parsons (4)

MEMBERSHIP

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Hosea Webster (4)
Theo. Stebbins (5)

PUBLICATION

D. S. Jacobus (1), *Chairman*
Fred R. Low (3)
H. F. J. Porter (2)
Geo. I. Rockwood (4)
Geo. M. Basford (5)

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Note—Numbers in parentheses indicate number of years the member has yet to serve

SPECIAL COMMITTEES

1910

On a Standard Tonnage Basis for Refrigeration

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John E. Sweet — H. H. Suplee
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1910

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J. W. Lieb, Jr., Chairman of the Library Committee, Am.Soc.M.E.

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1910

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J. R. Bibbins

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	1910			
Univ. of Maine, Orono, Me.	February 8	Arthur C. Jewett	H. N. Danforth	A. H. Blaisdell
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ADVERTISING SUPPLEMENT

SECTION 1

Machine Shop Equipment

Multi-stop and Double Turners

FIG. 1 illustrates the advantage of the *double stop* for each position of the turret, and the *double* adjustment of each turner. This piece has six finished diameters and six shoulders, and is turned by only three turners, which occupy only three positions on the turret. This not only leaves the remaining positions free for other tools, but it saves the operator the time and energy required to run the turret slide back each time.

All this is obtained without complication, and without introducing any features that are annoying when not in use.

In addition to the double stop for each of the six positions of the turret, we have an extra stop, consisting of a pin which may be dropped into any one of the six holes at the rear of the turret slide. This makes it possible to borrow five extra stops for any one of the tools, and gives to this tool seven length or shoulder stops, and leaves one stop for each of the remaining tools.

FIG. 1

The illustrations, Figs. 2 and 3, give examples of what one tool can do in this machine on chuck work, when we take advantage of the seven length stops and the seven shoulder stops of the cross-feed head.

Of course, in general practice three or four stops for one tool are all that will be needed, but since the modern cutting steels have greater durability, there is nothing lost by giving each tool all the work it can do.

Outer face and all shoulders and diameters accurately finished to independent stops by one tool. When roughing and finishing cuts are required, the roughing tool can be set near enough to use the same stops that are accurately set for the finishing tool. When an extra tool is used to give a roughing cut it is set as indicated by dotted lines in Figs. 2 and 3.

We find it difficult to illustrate all of the classes of work that can be turned out by this machine, but a little thought will suggest

HARTNESS FLAT TURRET LATHE

MAILED ON REQUEST

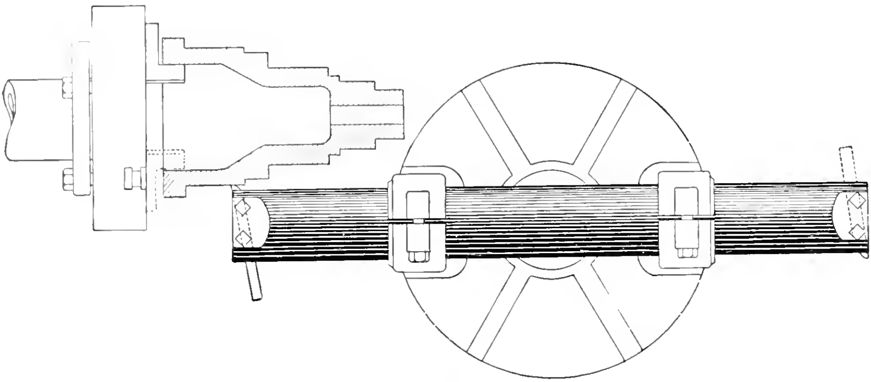

FIG. 2

many forms that may be readily handled in bar and chucking work, both steel and iron, on account of the many provisions for bringing both turret and cross slide up to fixed stops; either by power feed or by hand.

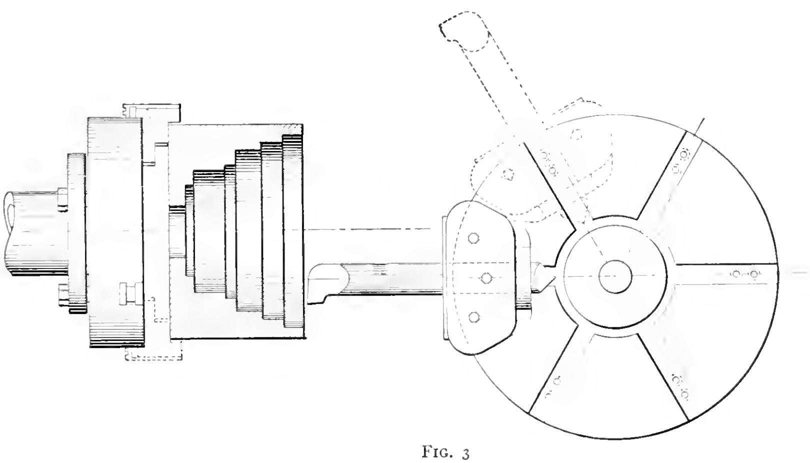

FIG. 3

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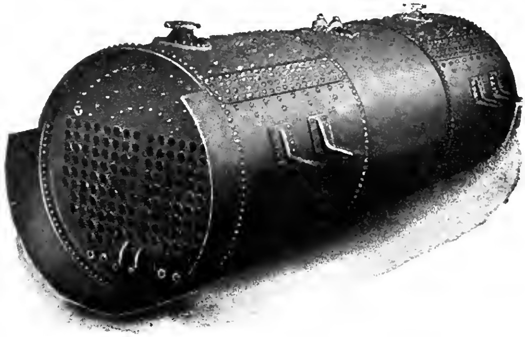
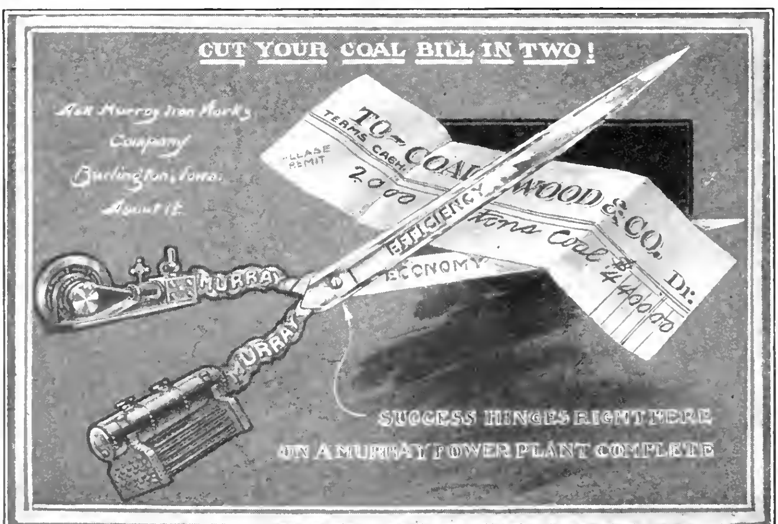
SECTION 2

Power Plant Equipment

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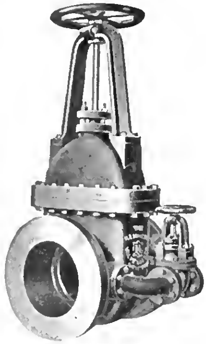

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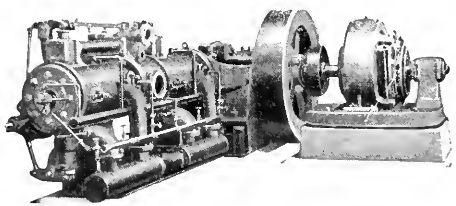

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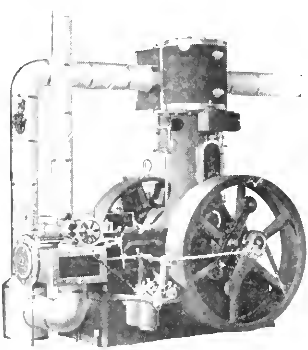

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SECTION 3

Electrical Equipment

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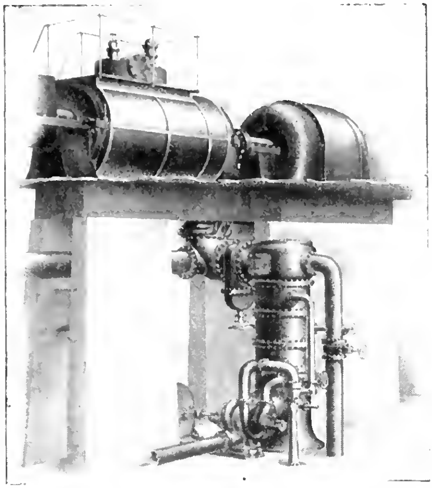
See Circular 501 for full Particulars



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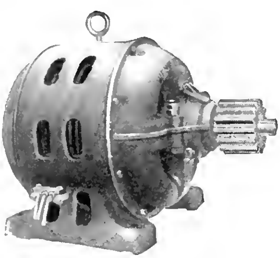

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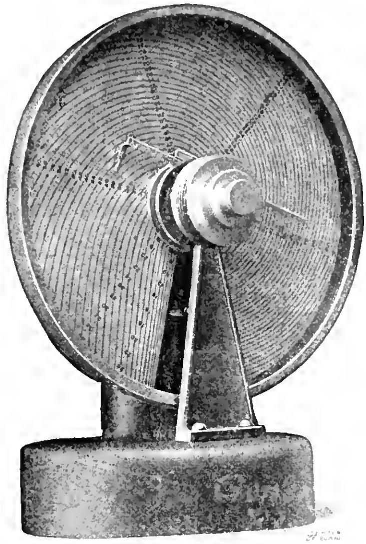
Measure the Steam in Your Plant

Know to a certainty how much is passing through your pipes. It's false economy to guess, when there is now available a simple, inexpensive and accurate meter for measuring a continuous flow of steam. The

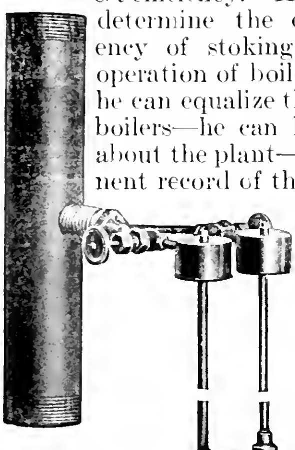
Flow GE Meter

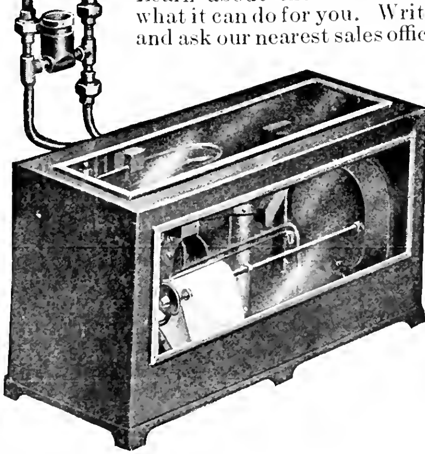


enables the power plant operator to discover leaks and losses and run his plant at its highest efficiency. He can determine the efficiency of stoking and operation of boilers—he can equalize the load on a battery of boilers—he can locate losses anywhere about the plant—he can obtain a permanent record of the amount of steam used for heating or manufacturing purposes, etc. The G-E Flow Meter is easily attached to a steam pipe by tapping a hole and inserting the proper sized nozzle plug. There is no friction error due to stuffing box or dash pot—no delicately adjusted parts to wear or corrode—nothing requiring attention. The G-E Flow Meter is thoroughly practical.

The *Indicating Steam Flow Meter* gives an instantaneous reading. It weighs but 25 lbs. and is portable, so that it can be carried around to any point in the plant.

Learn about the details of this new device and what it can do for you. Write for bulletin 4720-C, and ask our nearest sales office for full particulars.





The Recording Steam Flow Meter provides a continuous record of the total rate of flow in lbs. per hour. The Meter can be adapted by the attendant to any diameter of pipe and for any condition of temperature, moisture or pressure.

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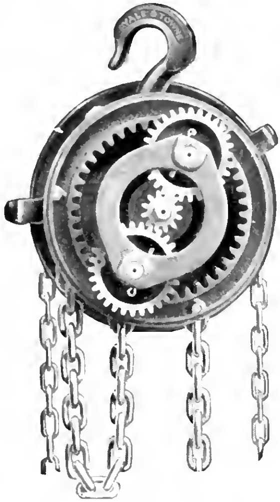

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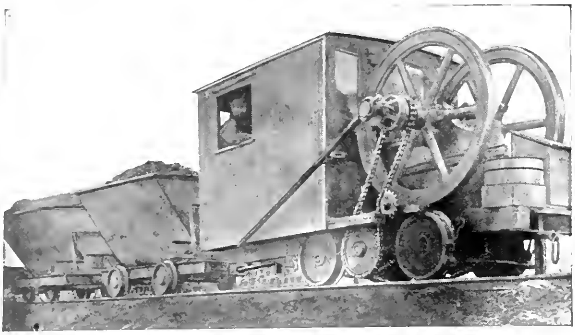

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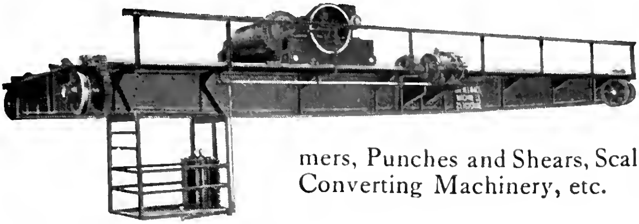

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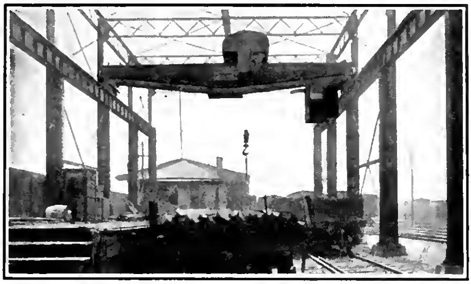

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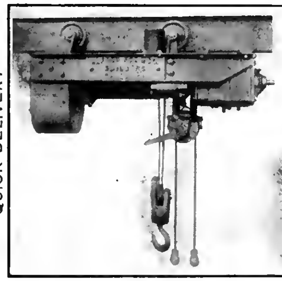

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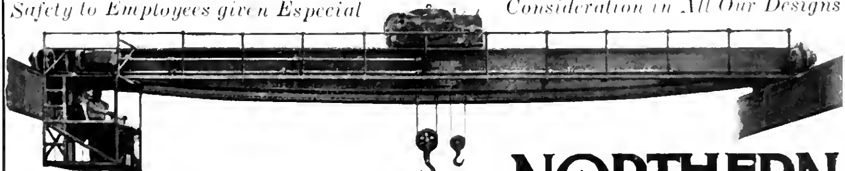

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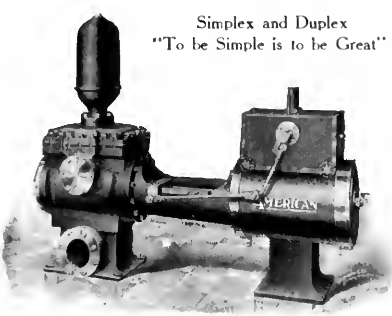

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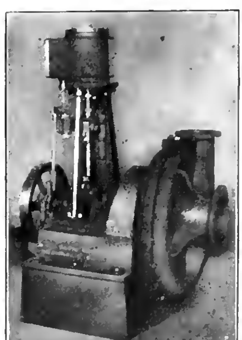

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SECTION 6

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